CEDSS

Domestic Support Operations vs CT Support Operations

Problems:

Medical Assistance:	Elderly & Infirm Triage Centers in coordination with Hospitals & Treatment Centers Evacuation & Treatment - Burn Centers
Communications:	Re-establish Regional & Inter-Agency Links
Intelligence/Information:	Differentiate & Direct
Asset Control & Management:	Mobile Hospital Units - Direct &Control Logistics - Food, Water, Medicine Transportation
Law Enforcement:	Coordinated and Directed

Center for Emergency Disaster Studies & Strategies

Evaluate Concepts & Principles of Available Domestic Support

Define the Roles and Responsibilities of all available Domestic Agencies and the limits and parameters of their Assistance

Legal Considerations & Restraints

Evaluate the Availability of Logistics and Limits on Support Operations

Develop Simulation Training Modules that Integrate the Lessons Learned from prior natural disasters and Integrate Available Agency Capabilities

Prepare Emergency Disaster Directors and Teams with realistic scenarios resulting from:

- Lesson Learned
- Resources Available (MOAs & MOUs)
- Technology Developed

Review and Integrate in a real-time mode, each new natural Disaster in light of the above considerations, and disseminate the lessons learned and experiences of participants.

Provide a Forum for the Exchange of Information, Development of Simulation Training Symposiums, Training of Emergency Personnel, and Stimulate Technology Development.

C^4I: Compounded Crisis Response Operations

Amidst the chaos and ravages that are part and parcel of natural disasters such as a Hurricane, Flood, Earthquake or Volcanic eruption, in the despair and frustration that inevitably becomes an integral part of the recovery, search and rescue, damage assessment and response initiatives that follow these disasters, imagine, if you would, that a group of people (terrorists) representing a foreign, unfriendly nation or perhaps, a dissident internal militia-type group were to strike at the very core of such an existing disaster. The introduction of a chemical or biological agent, by such a group, or even cataclysmic bombings of POL storage sites located in a disaster area, causing massive, additional casualties, would introduce a new and almost paralyzing element to events.

Such an attack, during a large-scale natural disaster could not be addressed, identified, treated or controlled due to the breakdown in normal command (Civil Authority), control (Law Enforcement) and communications (telephone, power, radio, television, transportation, etc.) links. No amount of normal disaster planning could predict such an event, nor prevent massive casualties, nor compensate for the overwhelming disruption to normal civil authorities recovery operations.

Existing disaster agencies, in addition to medical facilities and National Guard support assets, would all be overwhelmed by the speed and intensity of such events. and or their capabilities to deal with.

This type of attack would most probably be followed by an announcement of the group's responsibility for this terrorist act, with threats of additional further devastating strikes to follow, further exacerbating the public's helplessness and frustrations. This public acknowledgement of responsibility and the demands of the responsible individuals or group would be aimed at inducing public panic, which is the very goal of such a terrorist act.

Demands for a swift responses to these attacks and threats of further strikes, in the midst of the chaos that follows natural disasters, would be lost in the cries for assistance, from all levels of government assistance, and the inevitable inter-agency bickering that arises between agencies vying for lead authority (To determine whether there exists a Crime scene or a Disaster site). For example, in the Oklahoma City bombing, the immediate determination that a crime scene scenario existed requiring isolation of the entire area of the disaster, hampered rescue operations. The subsequent bickering over legal authority between agencies such as the FBI, AT&F, State Police or CT Task Forces, wasted precious rescue tasks. Every agency issued news releases via its PR coordinators, announcing that it was in charge and should be the only single coordinating agency addressing the situation.

Determining the extent of the threat and damage resulting from such an insidious attack would be hampered by:

Broken communications links,

Power out – Telephone lines severed – Emergency Crews Overwhelmed

Inaccessibility to the damaged areas,

Road networks inaccessible – trapped civilians require medical assistance or evacuation -

Overflowing casualty reports,

differentiate victims of natural disaster versus attack – determine level and type of assistance required – determine support assistance required – set up triage centers and direct victims to appropriate treatment centers.

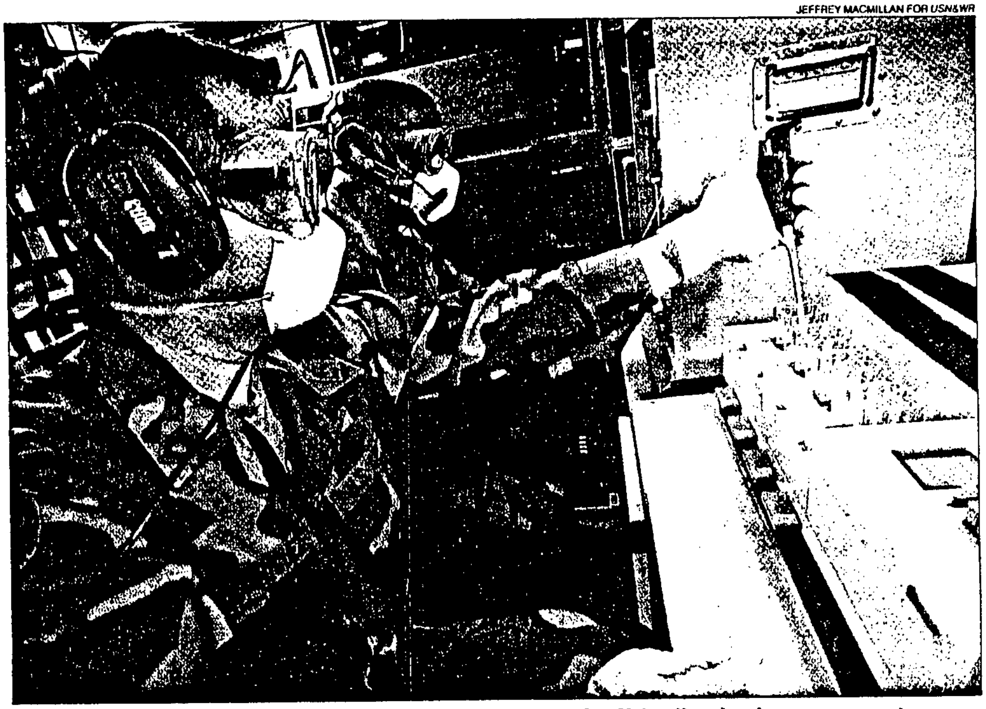
Evaluate which level of government (local, state, national or Joint Task Force) assistance is required and available:

- Biological – Chemical
- Medical supplies required – sources identified – support confirmed and coordinated
- Determine a needs assessment for military support –
    - Transportation
    - Medical assistance
        - Surgical teams
        - Medivac
        - Emergency treatment Centers
    - Communications support
        - Re-establish commo links to all elements of Recovery effort
    - Transportation assets
        - Vehicle & Aviation support
    - Technical support
        - Water purification units

    - Engineering equipment and teams
    - Decontamination units
- Logistics Support
    - Food – Medical Supplies
    - Portable food kitchens

The new terror fear: biological weapons

Detecting an attack is just the first problem



In the BIDS detector system, it can take a half-hour to determine if deadly microbes are present.

BY NICHOLAS HORROCK

America is stepping up preparations to cope with biological warfare. This month, at undisclosed locations in Denver, medical and weapons experts will begin to assess the city's ability to contend with terrorists using biological, radiological, or chemical weapons of mass destruction. Denver is the first of 120 cities where federal authorities will evaluate emergency capabilities under a $42.6 million Domestic Preparedness Program that is the largest civil defense initiative since the Cold War. This program begins two weeks after the Pentagon granted the first contract in a possible $400 million program to develop a detection system to sniff out deadly airborne microbes spread by an enemy.

Three events have created the new urgency: Iraq deployed missiles bearing anthrax germs, botulinum (a toxin that spreads the deadly disease botulism), and aflatoxin (a poison derived from mold) during the 1991 Persian Gulf war, and its biological weapons program continues, according to intelligence experts; a 1995 Tokyo attack in which the cultlike terrorist group Aum spread nerve gas in the subway system killing 12 people; and a little publicized conviction in Ohio last month of a microbiologist named Larry Wayne Harris, who pleaded guilty to fraudulently obtaining bubonic plague cultures. Harris, who has ties to right-wing groups, was sentenced to 18 months probation and community service. The plague cultures were obtained by Harris with such ease that in 1996 Congress tightened laws on commerce in deadly biological materials to make sure they were ordered for legitimate medical and scientific purposes.

Poor man's nukes. The CIA now says Iraq has been joined by North Korea, Iran, Libya, Syria, and even China in the quest to make biological weapons. Their motive is simple: Biologicals are cheaper and easier to make than nuclear or chemical weapons, and they can be equally as devastating. The U.S. Office of Technology Assessment once estimated that a small private plane, with 220 pounds of anthrax spores, flying over Washington on a clear, windless night, could trail an invisible, odorless mist that would kill between 1 million and 3 million people.

However, retired Army Col. Karl Lowe, an arms-control expert, argued in a recent essay that it would be very hard for terrorists to carry off a biological attack. Many biologicals can be dissipated by wind or rain, or must be ingested in such enormous amounts as to make their use as a weapon of mass destruction impossible.

Though difficult to execute, a biological attack would be virtually impossible to detect in its early stages. "Ideally we would like to develop a detection system using something remote, like a laser beam that could detect and identify a biological agent at standoff distances," says Assistant Defense Secretary Harold Smith. But that prospect is years away, so the Pentagon is trying to develop a "point detector" that could be mounted on a remote-controlled vehicle. It should be able to sniff air samples and determine within 15 minutes whether any of 26 dangerous agents are present, according to Brig. Gen. John Doesburg, whose command awarded the first contract for such a vehicle last month.

The best detector now is a Humvee mounted with what appears to be a small *Hansel and Gretel* house with three chimneys, named in the Army's cumbersome fashion the Biological Integrated Detection System, or BIDS. The problem with BIDS is that it takes two persons to operate, requires 30 to 45 minutes to identify biological agents (an eternity in combat), and can simultaneously identify only four. Next year, DOD will field a temporary improvement, the Air Base/Port Biological Detection system, at bases in two areas of high tension, like South Korea and Saudi Arabia.

On the civilian side, a law passed last year requires DOD to go beyond troop protection and assist in civil defense. An incident in Washington, D.C., last month added urgency to the effort. The headquarters of the B'nai B'rith, the national Jewish service organization, received a package with a threatening note and the laboratory words for anthrax on it. It turned out to be harmless, but had anthrax been loose in Washington's downtown, U.S. readiness would have faced the supreme test. ■

In a Test, Agencies Brace For a Terrorist Assault

Officials to Stage Mock Disaster in TriBeCa

By KIT R. ROANE

With an eye toward reducing the potential danger of a terrorist chemical attack, the city's Office of Emergency Management started a series of antiterrorism drills yesterday that will culminate today with a full-scale enactment of a toxic disaster in TriBeCa.

The drills, which began yesterday morning in 42 city hospitals, are designed to test the reaction of emergency response agencies to a chemical gas attack similar to the one that occurred in Tokyo two years ago. In that attack, members of the Aum Shinrikyo cult released homemade nerve gas on several subway cars, killing a dozen people and injuring 3,800 more.

The drill planned for today is to involve hundreds of city, state and Federal law enforcement officers. Although New York City's public safety departments staged a similar mock attack in a subway station one month after the disaster in Japan, law enforcement officials involved in today's test said that the city would be concentrating on an above-ground scenario.

"We are dealing with some new issues and want to figure out the best way to react to them," said Jerome Hauer, the director of the Mayor's Office of Emergency Management, who said the exercise has been nine months in the planning. "We are always trying to improve our emergency planning and response to various situations and this is nothing new. This is not in response to any real threat."

During a news conference yesterday, Mayor Rudolph W. Giuliani said that while there has been no specific threat, concerns were raised in March when the police responded to a report that 15 drums labeled Sarin gas — the type used in Tokyo by the Aum Shinrikyo cult — had been found in a house in Douglaston, Queens. The drums were later determined to have contained a harmless gas, but Mr. Giuliani said yesterday that he, the police and fire commissioners and Mr. Hauer "thought it would be a good idea to go through a formal exercise, just in case."

"The purpose of it is to improve our emergency procedures," the Mayor said. "There is no reason to believe that something like that is going to happen."

The exercise began yesterday morning with volunteers visiting the 42 hospitals with complaints of various symptoms of chemical exposure, Mr. Hauer said. The doctors and nurses at the hospitals, all of whom know that the symptoms were being reported as part of the test, were charged with figuring out the type of chemical exposure that matched the symptoms and how best to treat the victims without becoming a victim themselves or spreading the contamination.

This exercise is to continue today with nearly 1,000 law enforcement officers and emergency workers descending on a two-block area in TriBeCa with the mission of limiting the damage done by a hypothetical chemical attack.

"We regularly do disaster drills to keep the system in shape," said one law enforcement official, who spoke on condition of anonymity. "In this case, we know to be prepared, that it is going to happen, but haven't been given any particulars. Basically we will show up and if we step into a bad spot, we become victims."

Mr. Hauer said that eight weeks ago his office worked with Nassau County officials through a mock plane crash near Kennedy International Airport, hoping to improve inter-agency response to disasters like last year's crash of TWA Flight 800. He also said that $1 million in Department of Defense funds has been used for disaster-preparedness training for more than 3,600 New Yorkers, who went back to their various agencies and trained others.

Although city agencies have been conducting such training exercises for years, antiterrorism experts said that governments had increasingly been focusing on the complexities raised by chemical attacks since the attack in the Tokyo subways.

At 42 hospitals, the scenario of treating exposure to chemicals.

Brian Jenkins, the deputy chairman of the investigative consulting firm of Kroll Associates, noted that in the last two years several people have been arrested after brewing chemicals and labeling them Sarin gas. Others, he said, had taken to sending packages of a gelatinous substance to politicians they did not like. As opposed to the bombings that terrorists have employed in the past, Mr. Jenkins, who was also the RAND Corporation's research director on terrorism, said that any scenario where chemicals were used would be fraught with unknown difficulties.

Among them would be identifying the chemical used, figuring out whether the vapor was coming from a liquid or some type of dispersion device, and attempting to help victims without spreading the contamination.

"If you see people gasping, choking and falling down," he said, "do you immediately rush over and try to help evacuate people — thereby potentially becoming a victim yourself — or do you wait? This is not like a fire or explosion because chemical weapons require special handling. Ever since the Tokyo incident, a lot of people have been grappling with difficult issues like these."

Deadly Strike

The Pentagon takes aim against chemical and biological terrorism

By Katherine McIntire Peters

SANDY SCHAEFFER/MAI

The scenario was plausible: Congress was preparing to vote on controversial legislation that was sure to incite furor among extremist groups hostile to the government. Fearing a terrorist attack, Washington emergency and security workers were on alert. Just in case it was needed, a Marine Corps counter-terrorism unit was standing by at a naval base in Anacostia, a few miles south of Capitol Hill.

So when "terrorists" released the deadly nerve gas sarin into an underground parking garage across from the Rayburn House Office Building on April 30, the Marines and District of Columbia emergency personnel responded quickly in a portentous demonstration of how the military can assist local officials facing global threats. More than 100 Marines, many wearing chemical-protection suits and gas masks, and carrying electronic detection and monitoring equipment, swarmed the area around the garage, assisting "sick" pedestrians. The Marines quickly set up tents where patients could be sprayed with a bleach solution to decontaminate them so medical personnel could begin treatment.

Although the demonstration was staged, the threat is real. Two years ago, members of a Japanese cult killed 12 people and sickened nearly 5,000 others when they released sarin gas into the Tokyo subway. The incident heightened concern about the vulnerability of U.S. cities to similar acts of terrorism.

"Most of our adversaries now know better than to go against us force-on-force," says Lt. Col. Arthur Corbett, commander of the Marine Corps Chemical/Biological Incident Response Force (CBIRF), whose members participated in the demonstration. As a result, they are more likely to resort to terrorism, using biological and chemical weapons against U.S. troops and civilians, he says.

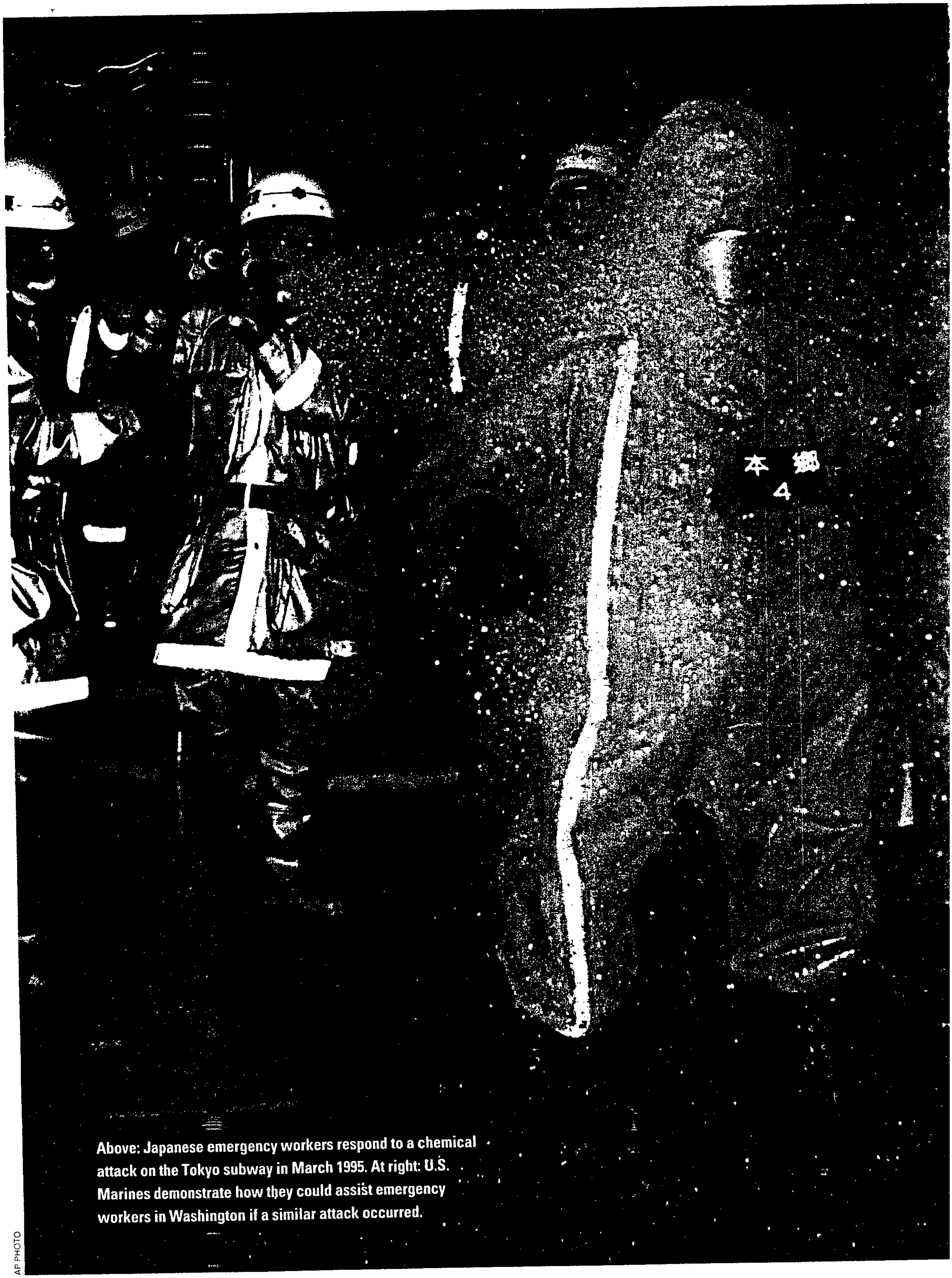
Biological and chemical weapons have long been considered the poor nation's nuclear weapon, because they are comparatively easy and cheap to develop and use and can kill thousands.

Defense officials estimate that about 30 countries possess mature chemical and biological weapons programs, at least 12 of which have advanced missile capabilities. In a speech at the University of Georgia in April, Defense Secretary William Cohen said, "This scenario of a nuclear, biological or chemical weapon in the hands of a terrorist cell or rogue nation is not only plausible, it's really quite real."

FBI Director Louis Freeh is so concerned about terrorism in the United States he has tripled the bureau's counterterrorism force over the last three years, raising to 2,600 the number of FBI personnel dedicated to the effort. The CIA, too, has weighed in with a recently created Terrorism Warning Group, "whose sole mission is to make sure that civilian and military leaders are alerted to specific terrorist threats," CIA Director George Tenet told the Senate Appropriations Committee in May. At the same hearing, Freeh said several Middle East terrorist organizations have U.S. cells, "which could be used to support terrorist activity here."

To beef up defenses against such an attack, the Federal Emergency Management Agency is heading up an interagency Domestic Preparedness Program to develop a coordinated federal response to terrorism and enhance state and local response capabilities.

The case for such a program was well-made April 24, just a week prior to the Marine Corps' Capitol Hill demonstration, when mail-room personnel at the Washington headquarters of the Jewish service organization B'nai B'rith discovered a package containing a broken Petri dish with a label suggesting it held the deadly bacterial agent anthrax. More than 100 workers were quarantined for over eight hours and several city blocks were cordoned off while emergency personnel responded to the situation. Because Washington firefighters do not have decontamination tents, some employees were forced to strip to their underwear in public while they were sprayed with a solution of bleach and



Above: Japanese emergency workers respond to a chemical attack on the Tokyo subway in March 1995. At right: U.S. Marines demonstrate how they could assist emergency workers in Washington if a similar attack occurred.

AP PHOTO

Marines assist local emergency response workers in the Washington drill, rushing stretchers to "sick" victims.

SANDY SCHAEFFER/MAI (2)

Emergency teams rush to help victims after a simulated chemical attack in a Capitol Hill parking garage.

water in case they had been exposed to the lethal agent. Only many hours later did scientists at the Naval Medical Research Institute in Bethesda, Md., determine the package was a hoax.

A Growing Arsenal

Under the Domestic Preparedness Program, the Defense Department will take the lead in evaluating and training officials in the 120 largest U.S. cities, beginning with 27 cities this year.

The 1997 Defense authorization bill provides $42.6 million for the program, including $6.6 million to support Health and Human Services Department metropolitan medical strike teams which could provide emergency health-care response following a terrorist attack. The Clinton administration requested an additional $48 million for the Defense Department's support for the Defense Preparedness Program in 1998.

The Capitol Hill demonstration sent a useful message about the resources the military can bring to bear in the event of an attack on civilians, says Lt. Gen. Charles Wilhelm, commander of U.S. Marine Corps Forces, Atlantic. Wilhelm established CBIRF in April 1996, under orders from Marine Corps Commandant Gen. Charles Krulak, who believed there was a need for a military unit dedicated to quick response to the growing chemical and biological terrorism threat.

"It's desirable to demonstrate to our own leaders and perhaps to others that we do in fact have this capability," Wilhelm says.

The unit has no direct counter-terrorism role, but instead is trained to provide an emergency response, decontaminate victims and establish a medical triage system. The unit also can quickly detect some chemical and biological agents, secure the area and help preserve the crime scene for law enforcement officials.

"Everybody wants to catch the fish but nobody wants to clean them," says Corbett, referring to the glamour of catching terrorists compared to dealing with the results of their acts. "We at CBIRF clean fish."

CBIRF is only one weapon in the Pentagon's growing arsenal to combat chemical and biological terrorism. The Pentagon is establishing a Chem-Bio Quick Response Force, which includes CBIRF, several Army research and tactical units, and the military's chemical depots.

Lt. Col. Timothy Madere commands the Army's Technical Escort Unit, based at Aberdeen Proving Ground, Md. The unit is expert at handling, dismantling and disposing of chemical and biological weapons. At a time when many units are facing cuts, the 152-member unit will grow to 180 positions to better handle their burgeoning mission list.

"We're very busy," Madere says. Last year, technical escort teams responded to hundreds of calls for assistance. The calls were for a range of things: A soldier digging a fox hole at Fort Polk, La., unearths a long-buried chemical weapon. Toxic gas released in a fire at a pesticide plant in Arkansas threatens to contaminate the environment and harm firefighters. A cache of biological bomblets is discovered buried at Wright Patterson Air Force Base in Ohio. Contractors working in Washington and New Jersey discover buried munitions in residential areas.

In each case, members of the Technical Escort Unit were dispatched to the scene within hours, sometimes minutes. Members are specially trained to handle a multitude of hazardous materials and operate sophisticated detection and monitoring equipment.

"My people do dangerous work," Madere says. "It's not pleasant or pretty."

While most of the calls for assistance are for accidents or to rectify the hazardous weapons disposal practices of the past, terrorism looms large. In March, New York City police arrested amateur chemist Lester Deily for reckless endangerment following a three-hour standoff after they were called to his home after receiving reports of hazardous material in his front yard. After the arrest, city officials called in members of the Technical Escort Unit when they discovered a canister labeled "Biological Hazard/Sarin Gas" in Deily's home, along with 200 gallons of jet fuel and other explosive material, scientific equipment and generators. The Army team removed the canister back to Aberdeen where they tested it for the gas. The canister proved empty, but the possibility that it contained the highly lethal nerve agent was real.

Rising Threat

The possibility of biological or chemical attack is a growing a concern at the Pentagon. In the Quadrennial Defense Review (QDR), the department's major review of military strategy and plans released in May, Defense planners recommended the department allocate $1 billion in new funding for defense against chemical and biological weapons.

The request for more funding for chemical and biological defense was music to the ears of Army Brig. Gen. John Doesburg, the Defense Department's joint program manager for biological defense.

"It's an enviable position to be in," he says. Extra money would likely go toward buying more protective suits, staging advanced technology demonstrations for protecting ports and airfields, and improving detection and response capabilities, he says.

In some respects, biological weapons pose a more serious threat than chemical weapons, Defense officials say. They are cheaper to make, far more deadly and harder to detect. Biological agents are odorless and colorless and symptoms may not develop until hours after an attack, during which time contamination may continue to spread.

Federal officials estimate that a small plane properly equipped could disperse enough anthrax to kill millions of people in a large metropolitan area. The invisible, odorless agent would not likely be detected until people began dying, hours later. By then, it would probably be too late to save those people infected but still living.

"Biological terrorism provides [paramilitary groups and terrorists] a means to make their point and to do it very dramatically," Doesburg says. Under Doesburg, the military is developing more sophisticated biological agent detection equipment. The military currently uses what's known as the Biological Integrated Detection System, a large unit that fits on the back of a Humvee and is operated by two people sitting inside—a mechanism far too cumbersome to be useful in a terrorist attack. Next year, Doesburg says, the Defense Department will field an interim system to better protect ports and air bases overseas.

"Biological terrorism provides [paramilitary groups and terrorists] a means to make their point very dramatically."

Army Brig. Gen. John Doesburg

Recent incidents have infused the issue with a sense of urgency. They include the sarin attack in Tokyo, Iraq's development of biological weapons discovered following the Persian Gulf War, and other less publicized incidents of rogue chemists tied to right-wing paramilitary groups obtaining biological agents.

"All of these things heighten the awareness of the vulnerability we have here in the United States—a very open society—to someone who wants to use this type of weapon," Doesburg says.

Critical Research

Forty miles north of Washington, scientists at the U.S. Army Medical Research Institute of Infectious Diseases at Fort Detrick, Md., don't need to read about the hazards of biological agents to understand the urgency. They work with the deadly agents every day at the institute—the only place in the United States where research is conducted in countering the use of biological agents as weapons.

"We are the only organization, not just in DoD, but in this country, that is focused on developing drugs and vaccines for these kinds of agents," says Col. David Franz, commander of the institute. The institute conducts research to develop strategies, products, information, procedures and training programs to medically defend against biological warfare threats.

Despite the institute's unique capability and mission, however, Franz expects he will have to further cut his staff of 430, already cut by one-third since 1991 when more than 600 civilian and military employees were assigned to the institute. While the QDR recommended more funding for chemical and biological defense, it also recommended major cuts to Defense infrastructure. As a research and development function of the medical community, the institute with its $20 million budget (down from $30 million in 1991) will be a prime target, Franz says. Such cuts could prove critical to efforts to defend against a biological attack.

While its staff and budget are shrinking, the institute's mission continues to grow. Institute staff routinely provide expert advice and assistance in handling biological agents to other federal agencies. During a biological attack, their contribution would be invaluable. "An expert who understands physical and biological characteristics of the agents and dissemination systems, even making recommendations via telephone, can make an enormous difference," Franz says. Because institute scientists study and handle biological agents on a daily basis, they are uniquely qualified to recommend appropriate management and response to a biological attack. Currently, institute employees are preparing training materials to be distributed to emergency workers through the Domestic Preparedness Program.

"While, public safety must be No. 1, expert evaluation of the real threat and a perfectly adequate, but measured response can snatch from the terrorist what he/she wants most: front page and live coverage," Franz says.

U.S. Targets

DoD will work with emergency personnel in 27 cities this year to assess vulnerability to terrorist attack. Workers in 120 cities will be trained to cope with such attacks.

Anchorage, Alaska	Los Angeles
Atlanta	Memphis, Tenn.
Baltimore	Miami
Boston	Milwaukee
Chicago	New York
Columbus, Ohio	Phoenix
Dallas	Philadelphia
Denver	San Antonio
Detroit	San Diego
Honolulu	San Francisco
Houston	San Jose, Calif.
Indianapolis	Seattle
Jacksonville, Fla.	Washington
Kansas City, Mo.	

Battlefield threats are easier to defend against than terrorism, Franz says. During war, soldiers may be vaccinated against likely biological agents or, if vaccines are not available, they may at least be trained and prepared with medical antidotes should they become infected.

"Terrorism is such a tough problem," Franz says. "The opportunity to prepare for a specific terrorist incident will be extremely rare—much like preparing for an emerging disease outbreak. Unless we happen to have excellent intelligence, we can only be prepared to respond after the fact."

Fear Factor

While the physical danger of biological weapons is real, the psychological danger may be just as debilitating.

During the Persian Gulf War, Iraq's chemical and biological weapons capability was widely discussed in the press and assumed to be extensive. Between January 18 and February 28, 1991, Iraq sent 39 Scud missiles into Israel. While there were only two deaths associated with the missile attacks, more than 1,000 people were medically treated. More than half were treated for anxiety and 230 were hospitalized for overdosing on atropine, taken as a result of the attacks, Franz wrote in a pamphlet titled "Defense Against Toxin Weapons." If even one of the warheads contained a biological agent which killed or sickened a few people, the terror effect would have been even greater," he wrote.

While Iraq did in fact have a biological capability—they had produced anthrax and botulinim (10,000 times more potent than sarin) and were capable of disseminating them from the air—weather and battlefield conditions (the coalition forces maintained control of the air) rendered the weapons militarily ineffective.

"If everything had worked out just right for [the Iraqis] they could have created mass casualties. But much of what they did could have had enormous psychological effect," Franz says. "They could have almost shut us down. Maybe not killed thousands, but they could have shut us down as an effective force by the fear factor and the panic. Even if they only made a few people sick it would have been very effective," he says.

Franz downplays the Iraqi threat because he's seen what the Russians are capable of: "It makes Iraq look like a Sunday School picnic. [The Russians] have just enormous capability and they worked for years and years to develop that capability."

At the height of the Cold War, in 1972, the United States and the Soviet Union pledged to end their development of biological weapons with the signing of the Biological Weapons Convention. The United States then ended its biological weapons program, destroying all weapons and continuing research only into the medical defense against and detection of biological weapons.

But in 1979, U.S. intelligence officials grew suspicious of Soviet intentions when dozens, perhaps hundreds, of people mysteriously died in Sverdlovsk, a city in the Ural Mountains. The Soviets attributed the deaths to food poisoning, but U.S. officials suspected an accidental release of a biological weapon.

U.S. fears were confirmed in 1992, when Russian President Boris Yeltsin acknowledged the Soviets had continued their program on a large scale. Yeltsin then signed the Trilateral Joint Statement on Biological Weapons with the United States and Britain to limit proliferation. The 1979 deaths in Sverdlovsk were in fact caused by the inadvertent release of anthrax from a nearby biological weapons facility. The wind carried the anthrax spores 40 kilometers, killing dozens of people and livestock. Officials at the facility apparently weren't aware of the accidental release until people began to die unexpectedly.

Franz was a member of the first two teams to visit Russia and tour some nonmilitary biological facilities—military facilities remain closed to U.S. inspectors.

"The Russians have developed and tested [an effective] program," Franz says. "A lot of that is still classified, but they certainly did their homework and they worked on a lot of different agents and a lot of different delivery systems and are capable of producing large quantities of biological weapons."

While the break up of the Soviet Union eased the threat of conventional warfare, it has only exacerbated the threat of biological terrorism, Franz says. "We're concerned about what happened to all those scientists. They had enormous facilities and thousands of people working on these issues. And they're broke now."

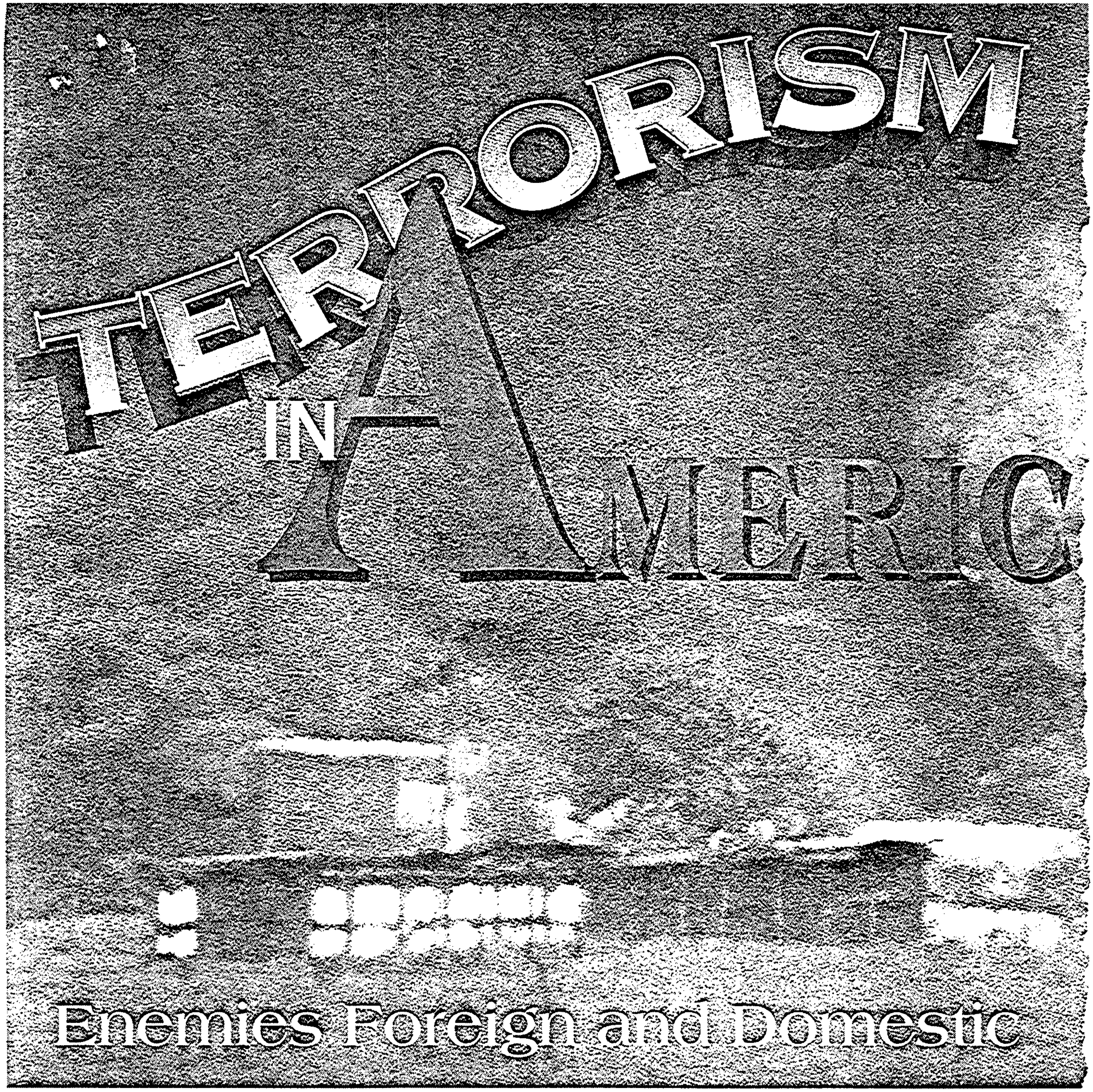
The U.S. government is working with Russia and former Soviet states to channel scientific efforts into non-military research and development. Nonetheless, there is a fear some of those scientists may sell their skills and expertise to rogue nations and sponsors of terrorism.

"I believe in order to make an effective terrorist weapon that will wipe out half of a city, you will need state sponsorship," Franz says. "You're not going to make [such an agent] in your bathtub in Rockville."

"That's the good news. The bad news is, with the break up of the Soviet Union, that capability is out there, and there are people who are interested in obtaining it." □

TERRORISM IN AMERICA

Enemies Foreign and Domestic



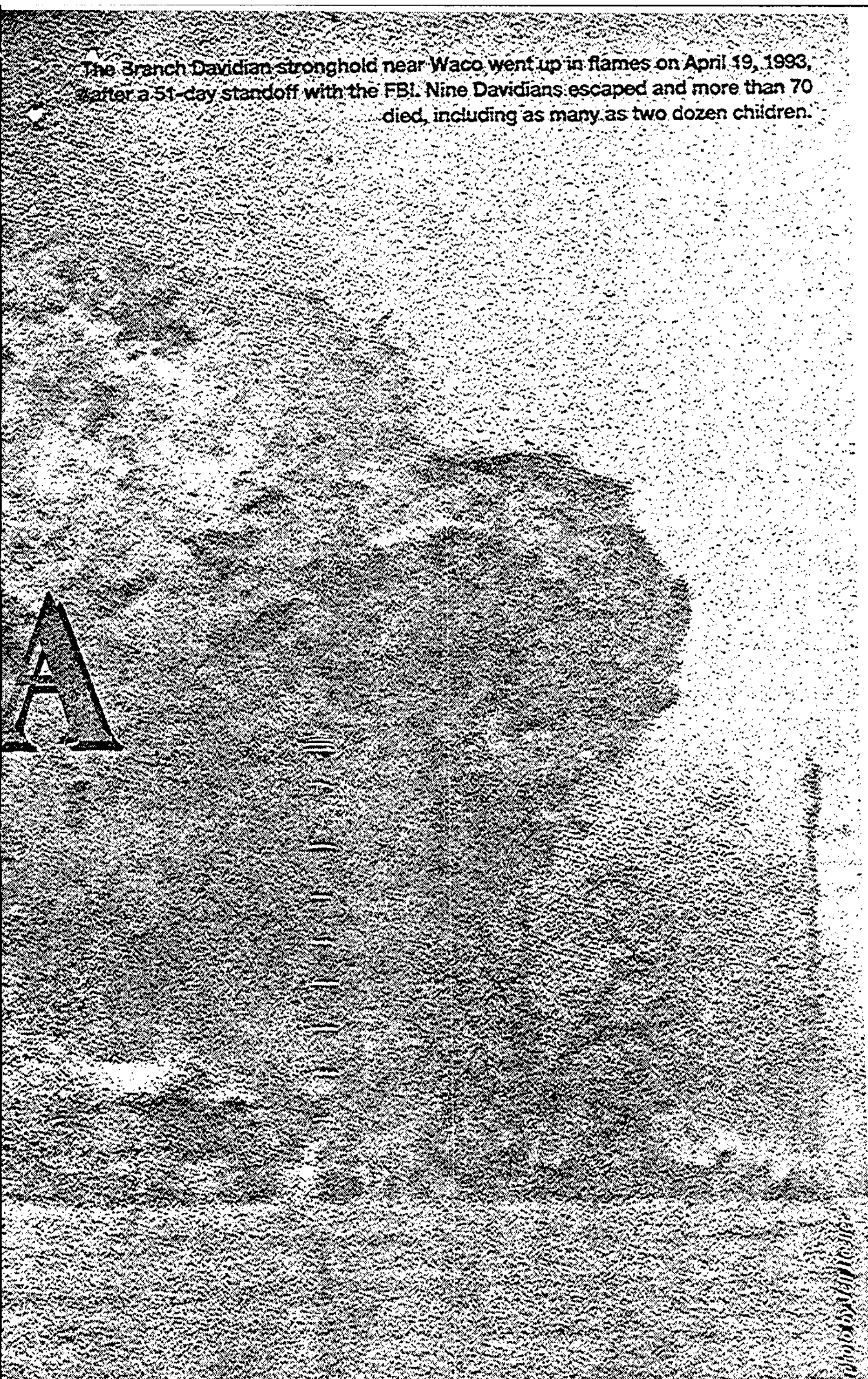
By Richard Abshire

Terrorism is a controversial subject as old as history and as timely as the Oklahoma City bombing trial. Americans are still reeling from the shock of realizing that we are not immune to its contagion, a condition aggravated by a lack of historical perspective, the still-fresh images of a bombed-out day care center in the Alfred P. Murrah building, and the confusion among experts and civilians alike about exactly what terrorism is.

Terrorism in America

In one form or another, what we call terrorism today has been a part of life in this country since before it was a country, from colonial border raids and Indian Wars to pre-Civil War Bloody Kansas and the first and second generations of the Ku Klux Klan. In the early 1950s, Puerto Rican nationalists shot up the House of Representatives and lost a gun battle with President Truman's security detail as he stepped out the front door of his temporary home at the Blair House. A number of 1960s radical groups viewed bombings as political statements, armed robberies as appropriations, and assassination as street theater.

In the 1970s, international terrorism became a fact of life in Europe and the Middle East. Here at home there were isolated bombings, a short-lived wave



The Branch Davidian stronghold near Waco went up in flames on April 19, 1993, after a 51-day standoff with the FBI. Nine Davidians escaped and more than 70 died, including as many as two dozen children.

of airliner highjackings and the Letelier assassination in Washington DC, but by and large Americans enjoyed the illusion of immunity. In the 1980s in Washington DC, Los Angeles and Utah, terrorists murdered two Iranian opponents of the Ayatollah Khomeini and a pair of Libyan college students who reportedly had offended the Qadaffi regime. A series of planned bombing campaigns targeting New York City and Washington DC were aborted by timely arrests between 1987 and 1989. By and large, America's luck held.

Over the last 25 years, while American interests were among the most frequently targeted by terrorists abroad, domestic terrorist incidents remained among the lowest in the world. The FBI reported only four in 1992.

But the reality of our domestic vulnerability was brought home for the first time in February 1993, by the bombing of the World Trade Center in New York City by Islamic fundamentalists. Six Americans died and 1,000 were injured in an attack against civilians that its designers had intended to be much worse. In June of that year, authorities uncovered a second plot by another Islamic terrorist cell to bomb the United Nations building as well as commuter tunnels and a bridge between New Jersey and Manhattan, all in conjunction with a planned armed raid on the headquarters of the FBI's New York field office.

By and large, America has enjoyed the illusion of immunity to terrorism within its borders. But with incidents like the bombing of the World Trade Center and the federal building in Oklahoma City, reality is hitting Americans hard.

Given the unforgettable images of the World Trade Center bombing and the trials of Islamic fundamentalists charged with its planning and execution, it is not surprising that many Americans' suspicions turned to the Middle East on the morning of April 19, 1995, when news first broke of the bombing of the federal building in Oklahoma City.

There had been incidents involving ultra-environmentalists out West and anti-abortion groups around the country, and a white separatist group calling itself The Order that launched an 18-month crime wave in the Pacific Northwest in 1983-84. But the main threat for years had been foreigners nursing grievances born of war and politics on the other side of the world.

But there were people around the country who watched the news from Oklahoma City and knew the significance of the date, April 19. They suspected that Ruby Ridge, Waco and the Brady Bill had fundamentally altered

TERRORISM IN AMERICA

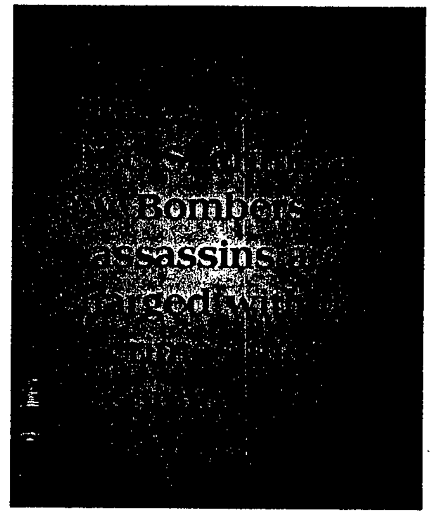
the landscape of terrorism in America and speculated that the culprits, this time, were much closer to home.

The definition problem

Any discussion of terrorism has to address the problem of definitions. It is a problem because there is no more than the most general agreement on what terrorism is. As terrorism expert Brian Jenkins noted several years ago, terrorism has become a "fad" word, indiscriminately applied to fit a wide range of interests and agendas. For the record, the Federal Bureau of Investigation, defines terrorism as "... the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof in furtherance of political or social objectives."

This seems straightforward enough, but there are problems. For one thing, according to a 1995 study by RAND, a nonprofit think tank for the National Institute of Justice, the FBI doesn't seem to follow its own definition in reporting incidents. For example, according to the report, the FBI does not classify as terrorist acts "... many hateful acts and crimes that might, at first glance, appear to meet the bureau's definition... racially or religiously motivated acts of violence, so-called hate crimes... attacks on medical clinics performing abortions, attacks on laboratories and clinics performing experiments on animals, and the sabotaging of logging operations..." The report goes on to explain, "Generally, in addition to the definition... the FBI also seeks a conspiratorial dimension when evaluating potential acts of terrorism... [which] might include evidence that more than one crime was intended to be committed, or that a network of individuals prepared to carry out additional acts stands behind lone perpetrators. Thus, the murder of abortionist Dr. Gunn in Pensacola, Florida, was considered an isolated criminal act, in large part because evidence depicting a conspiracy was lacking."

Another problem the RAND study found was that state and local law enforcement agencies apparently don't subscribe to the FBI's definitions. They do consider skinhead thuggery, abortion clinic bombings and sabotage



by radical environmentalists terrorism and many of these agencies, according to the RAND report, may not be aware that all terrorist incidents are to be reported to the FBI for investigation. When local agencies do report incidents to the FBI, the FBI often does

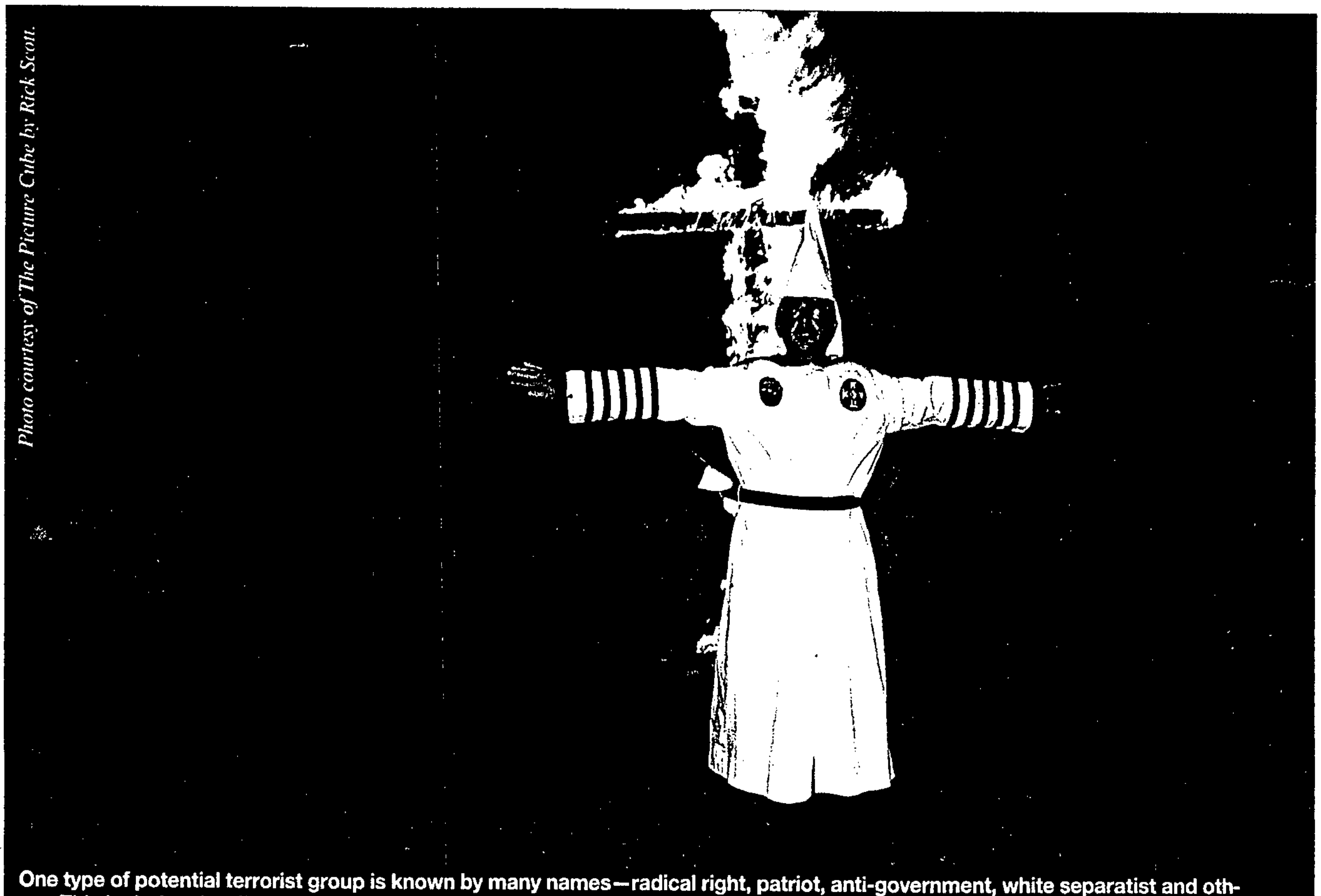


Photo courtesy of The Picture Cube by Rick Scott.

One type of potential terrorist group is known by many names—radical right, patriot, anti-government, white separatist and others. This includes the Klan and all its offspring: the American Nazi Party, the Birchers, Minutemen, Posse Comitatus, et cetera.

not include them in its annual report because the incidents don't meet the federal criteria. All of this is complicated by the fact that there is no such thing as terrorism in our criminal law. Bombers and assassins are not charged with terrorism, they are charged with the crimes they commit. So it's not clear how much value there is in all the semantic armwrestling to begin with, although federal legislation, including the new anti-terrorism bill, may provide some advantage in cases that fit the federal definition.

For the record, two terms that are often used interchangeably actually have different and specific meanings. According

> [illegible] at least 44 [illegible] across the country [illegible] had at least one. . . Some [illegible] have only a few [illegible] others have more [illegible] a thousand [illegible]

to the RAND report and other authoritative sources, "anti-terrorism" refers to activities intended to prevent terrorist acts. "Counter-terrorism," on other hand, refers to activities that respond to terrorist acts once they have occurred. In other words, police intelligence operations and target-hardening measures are anti-terrorist; SWAT teams are counter-terrorist.

U.S. terrorist organizations

The RAND report identifies five potential types of terrorist organizations in the United States: ethnic separatist and emigre groups, left-wing radicals, issue-oriented groups, foreign terrorists and right-wing groups.

Historically, ethnic/emigre groups have been some of the most violent, although this has not been the case in recent years. These groups use the U.S. as a battleground for causes that may have little to do with domestic policies of the American government. They have been responsible for bombings in major American cities, and their activities often cluster in ethnic enclaves where radical attitudes are sometimes handed down to succeeding generations.

Left-wing radicals were most active during the Vietnam era and are less of a factor today, although some experts classify single-issue groups such as ultra-environmentalists and animal rights radicals as left-wing. In fact, there has been published supposition that the alleged "Unabomber" may have been influenced, at least in target selection, by exposure to materials made available at an Earth First conference. Spokespersons for Earth First have denied that the suspect now in custody was a member of the group.

In addition to environmental and animal rights groups, the most prominent single-issue radical groups of interest are those responsible for anti-abortion violence that has included a series of clinic bombings and possible involvement in attacks on doctors. In many areas of the country these have been the groups of primary concern to date.

Until the bombing in Oklahoma City, foreign terrorist groups had been responsible for more actual damage than any other groups in recent history. Foreign terrorists were behind the World Trade Center bombing and a laundry list of planned bombing campaigns targeting New York City and Washington DC throughout the 1980s and early 1990s, as well as the Pan Am Flight 103 mass murder in Lockerbie, Scotland.

International terrorism resists analysis and prediction because any linkages of cause and effect that may come into play are often distant in time and place.

Experts originally theorized that the Pan Am 103 bombing was ordered by Iran in retaliation for the accidental downing of an Iranian airliner by a U.S. Navy ship on patrol in the Arabian Gulf months before. While there may have been a connection, investigators subsequently named two officers of the Libyan intelligence service as having supervised the actual operation.

Yu Kikumura, identified as a Japanese terrorist sent to the United States to launch a campaign of bombing in Manhattan in 1989, was allegedly acting under the orders of Colonel Qadaffi of Libya, in retaliation for a U.S. bombing mission against Libya two years before. The air raid on Libya, in turn, was in retaliation for Qadaffi's suspected involvement in the bombing of a German nightclub frequented by off-duty U.S. military personnel.

On the international scene, as the decades of Israeli-Palestinian violence suggest, cause and effect often blur in an endless series of strikes and counter-strikes in which all sides accuse their enemies of terrorism and claim the right of self defense.

The fifth type of potential terrorist organization is known by many differ-

April 19 has gained significance among some militia groups as a day of reckoning. The bombing of the Alfred P. Murrah federal building in Oklahoma City last year is thought to have been carefully planned for that date.

ent names — radical right, patriot, anti-government, white separatist, white supremacist, survivalist, tax resisters, etc. It is basically a collage of radical groups and individuals whose core members trace their genealogy to the Cold War. Since World War II, a looseknit family of groups on the far right has evolved across the country. From the taproot, the Klan and all its offspring, to the American Nazi Party,

> bombing in Oklahoma City was done by Middle Easterners, some recognized the M.O. as a militia calling card

the Birchers, Minutemen and later Posse Comitatus and others, these groups never constituted more than a radical fringe. And they spent more time and energy squabbling amongst themselves than pursuing a cogent agenda.

One of the few things many of them did share to some extent was Christian Identity, a racist, anti-semitic pseudo-religion based on a 19th century interpretation of Scripture that holds that Anglo-Saxons are the lost tribes of Israel. According to Christian Identity, modern Jews are literally descendants of Satan, and persons of color are non-human "mud people." Even with this in common, though, conflict continued over doctrinal minutiae among the various factions.

Right-wing radicals had high hopes of recruiting Midwest farmers hit hard by the farm crisis of the 1980s, but were largely disappointed. It wasn't until 1992 and 1993 that events created an atmosphere in which their message would find a broad audience.

The Randy Weaver standoff in August 1992 at Ruby Ridge, Idaho, in which Weaver's teenaged wife and son and a U.S. deputy marshal were killed, was a godsend for radical propagandists who cast the Weavers as martyrs in a holy war against ZOG, the "Zionist Occupation Government."

Organized fringe

Morris Dees is the founder and chief trial counsel for the Southern Poverty Law Center, home of the Klanwatch Project and Militia Task Force. In his book, "Gathering Storm - America's Militia Threat," he reports that in October 1992, 160 white men, a "true cross-section of the far-right movement" met in a hotel conference room in Estes Park, Colorado, for a weekend of speeches, strategic planning and committee work designed to organize the movement and expand its appeal. Two main themes were struck there, according to Dees. First, attendees were admonished to avoid blatantly racist and anti-semitic rhetoric and to focus on the federal government as the common enemy. Second, a strategy was forged based on 18th and 19th century militias and vigilantism, that would lead in the months to follow to what we now know as the militia movement.

Of that conference Dees writes, "During that weekend in the Rockies, a network of militant anti-government zealots was created. . . . The Rocky Mountain Rendezvous. . .was a watershed for the racist right."

The Branch Davidian stronghold near Waco went up in flames on April 19, 1993, after a 51-day standoff with the FBI. Nine Davidians escaped and more than 70 died, including as many as two dozen children. The Patriot movement was not alone in decrying the performance of federal agencies at Waco. In addition to critics in Congress and elsewhere, the National Rifle Association was especially harsh in its comments, and public opinion generally was mixed on the government's conduct. While the outcomes of the two stand-offs were unquestionably and tragically unacceptable, movement sympathizers rejected any suggestion that they were the results of honest miscalculations or even incompetence. They insisted that it was the evil intent of ZOG to make examples of the Weavers and the Davidians, and that April 19 was the moral equivalent of Pearl Harbor.

When Congress passed the Brady Bill later that year, the militia movement caught on like a brushfire. Again quoting Morris Dees, "Between 1994 and 1996, there were at least 441 militia units across the country. Every state had at least one. . . . Some units have only a few members; others have more than a thousand. In addition. . . 368 allied Patriot groups promoted the formation of militias."

In a letter to Janet Reno on October 24, 1994, Dees wrote, "Our office has confirmed the active involvement of a number of well-known white supremacists, Posse Comitatus, Identity Christian and other extremist leaders and groups in the growing militia movement."

According to most observers, there is a distinction to be made between rank and file militia members and long-time extremists. Average militia members tend to be lower to middle-income white men worried about economic security as well as government excesses and what they believe are their Second Amendment gun ownership rights. Long-time extremists appear to be encouraging the militia movement in furtherance of their own radical, and often violent, aims.

As related movements gained attention, the factions within began to form their own courts. They issued arrest warrants for government officials and filed bogus liens on anyone who drew their ire. Anti-government sentiment was fed through newsletters, computer bulletin boards and short-wave radio programs whose rhetoric grew increasingly heated and paranoid. The groups' delusions included believing that they were targeted for preemptive strikes, that Russian tanks were hidden on American military bases and that at any moment an order would be sent out to round up members and place them in concentration camps such as the one disguised as a new airport in Denver.

Amid the propaganda of hate, fear and paranoia, there were ample indications that April 19, 1995, would be a special day for the movement. The bulk of the March 1995 issue of the Militia of Montana's newsletter was devoted to the case of Richard Wayne Snell, a movement hero. Snell was

In addition to environmental and animal rights groups, the most prominent single-issue left-wing radical groups are those responsible for anti-abortion violence including clinic bombings and attacks on doctors. The murder of a Florida abortion doctor was not considered a terrorist act by the FBI because evidence of conspiracy was lacking.

scheduled to be executed on April 19 for the murders of a black Arkansas state trooper and a man Snell allegedly misidentified as a Jewish pawnbroker. The MOM newsletter linked the date of his pending execution to the dates of the Randy Weaver firefight, the British burning of Lexington in 1776, and the 1993 conflagration at Waco. An associate had reportedly threatened Snell's clemency board with the wrath of God

> force or violence against persons to intimidate or coerce a govemment, [or] the civilian population, in furtherance of political or social objectives.
> —The FBI

if Snell was executed. In other news, a group described as having "Identity leanings" announced an event to honor the Davidians and to protest Snell's execution at a Confederate memorial park in Arkansas on April 19. And of course ceremonies were planned at the Mount Carmel site near Waco as well.

And that is why a number of people around the country, Morris Dees and his associates included, didn't necessarily think first of Middle Eastern terrorists when they heard the news from Oklahoma City. That is why they suspected that the truth lay closer to home. After all, they had read "The Turner Diaries," a novel written in 1978 in which a fictional group called The Order begins an ultra-violent civil war in America with the destruction of FBI headquarters in Washington by a 5000-pound ammonium nitrate and fuel oil (ANFO) truck bomb. And those who have followed the movement know that more than 200,000 copies of "The Turner Diaries" have been sold at gun shows and movement meetings over the years. They know that it is a bible to many in the movement today, and that there are prophets aplenty crying out in the wilderness that the time has come to put their faith into action.

But what even the most knowledgeable observers don't know is whether Oklahoma City was an isolated incident or the Fort Sumter of America's second Civil War. ❑

Richard Abshire is a former police captain and SWAT commander, a graduate of FBI and U.S. Secret Service terrorism, hostage negotiations and dignitary protection schools. He is a regular contributor to this magazine.

Coming Next Month

Terrorism in America

Part Two: Today & Tomorrow

Where do we go from here? Which is the greater threat to America's future, international or domestic terrorism? What can law enforcement do about it, and what role will the new anti-terrorist law play? Find out what the experts think in the next issue of LET.

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Team and Technology

STRIKER 40mm

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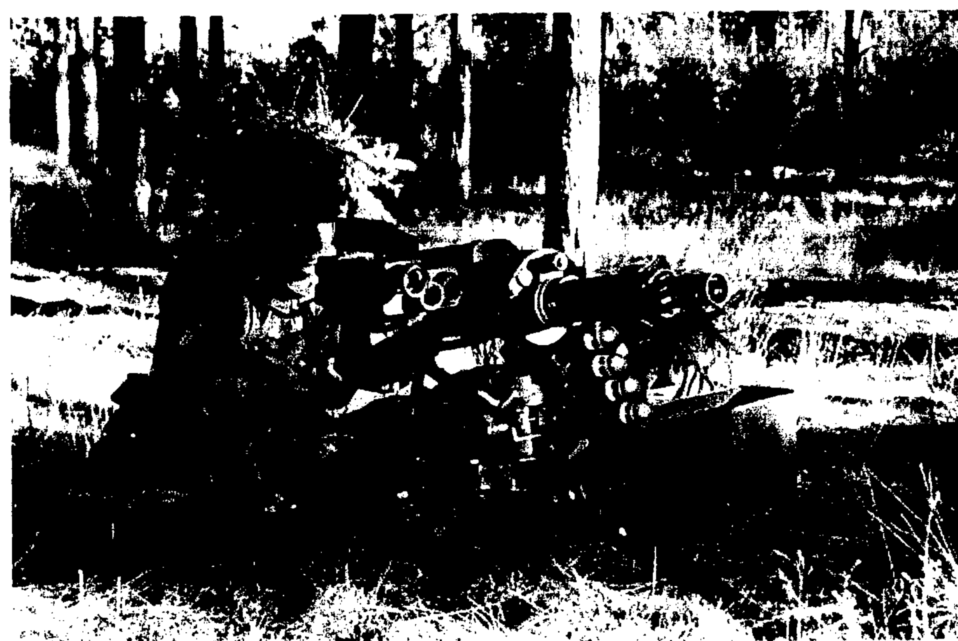

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Crew Served Weapons

Spanish-American War
World War I

Maxium &
Gatling Gun

WWII

.50cal Browning

Somalia & Gulf Wars
1968-1992

MK19 Bursting
Munition

2000

STRIKER
40mm AGL
Air-Bursting
Programable
Ammunition &
Weapon

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The Weapon

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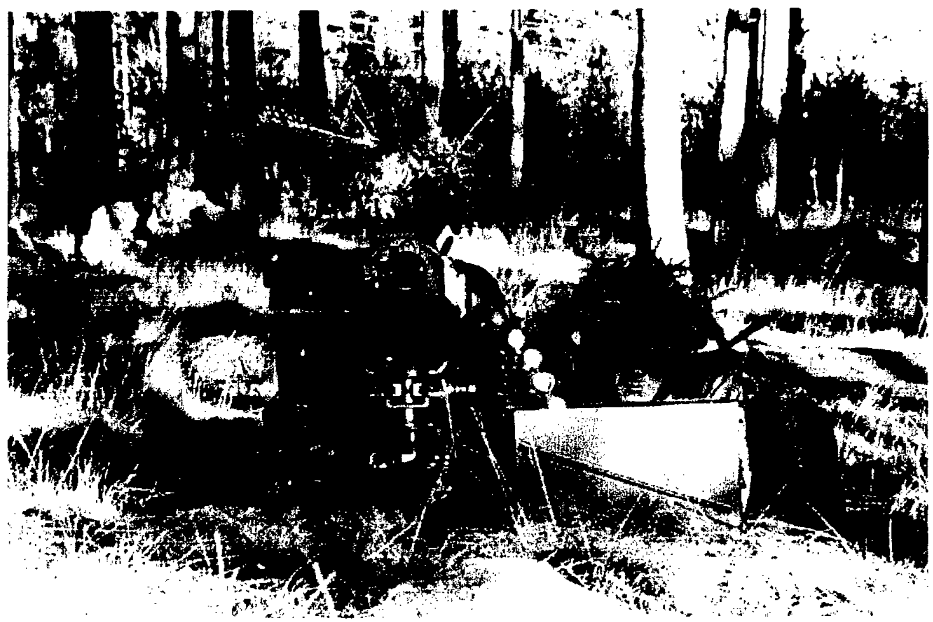
SacoDefense incorporated

- Lethal
- Smart
- Precise
- Portable
- Cost Effective



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CELSIUS GROUP

Computing Devices Canada

Company Funded Development

*Use of **Computer Modeling** in Design/Development allowed Saco to explore various designs and find the **OPTIMUM Crew-Served Weapon Design***

Team Formed with
State Department
Approval 1995

BOFORS Fields "**3P**" Air-Burst 40mm
Ammunition to Sweden 1993-1995

Alpha Protoype Development 1993-94

CDC Develops Initial
LVS Brassboard
1991-1993

Gun Brass Board R&D 1990-1991

SACO Comissions Gene Stoner 1988

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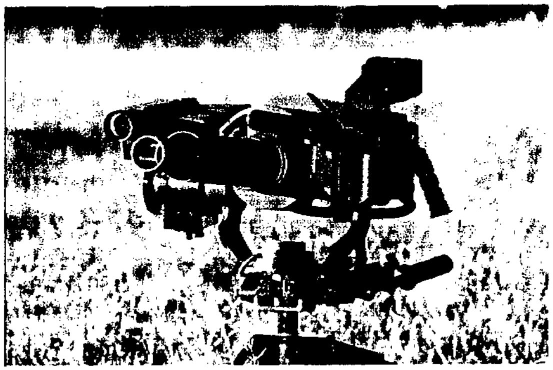
Development & Testing



Air-Bursting Ammunition Tested 1996

Gun-Sight-Ammunition System Integration 1997

Ready for IOT&E

Production Designs Verified 1997-1998

Customer Focus Groups 1996-1997 MANPRINT Focus

Beta Weapon Prototype Development 1994-96

Testing 1994-1998

Cookoff

Endurance

Reliability

Sand & Dust

Safety

Extreme Hot & Cold

Ammunition Compatibility

Accuracy & Dispersion

ATF

BRING US CHALLENGES . . .
. . . WE RETURN SOLUTIONS

ARMAMENT TECHNOLOGY FACILITY
COMMERCIAL: 201-724-4ATF
DSN 880-4ATF

SacoDefense incorporated | BOFORS CARL GUSTAF CELSIUS GROUP | Computing Devices Canada

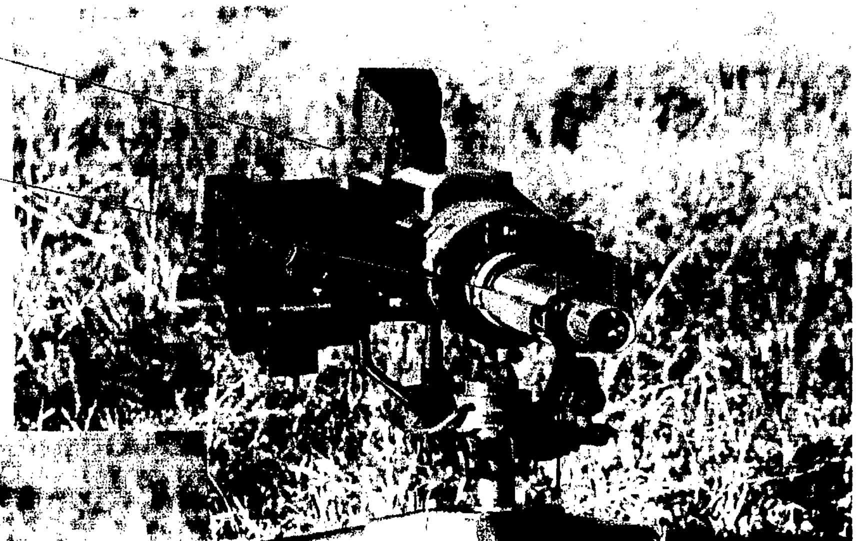
Packed with Technology

Computer Processor
Range Finder & Sensors

Ammunition Programming

Optimized Rate of Fire

Low Dispersion Weapon



Light, Low Recoil Weapon

Lightweight Gun Action Technology

Quick Slew Mount

Fine Adjust

SacoDefense incorporated | BOFORS CARL GUSTAF CELSIUS GROUP | Computing Devices Canada

Soldier Display

Electronic Range Card

Adjusted Aim Point

Predesignates Targets

Software

Laser Aim Pointer

Range

Computing Devices Canada

Day / Night

Azimuth

Soldier Controls

LRF Trigger
Weapon Trigger
Mouse (Toggle)

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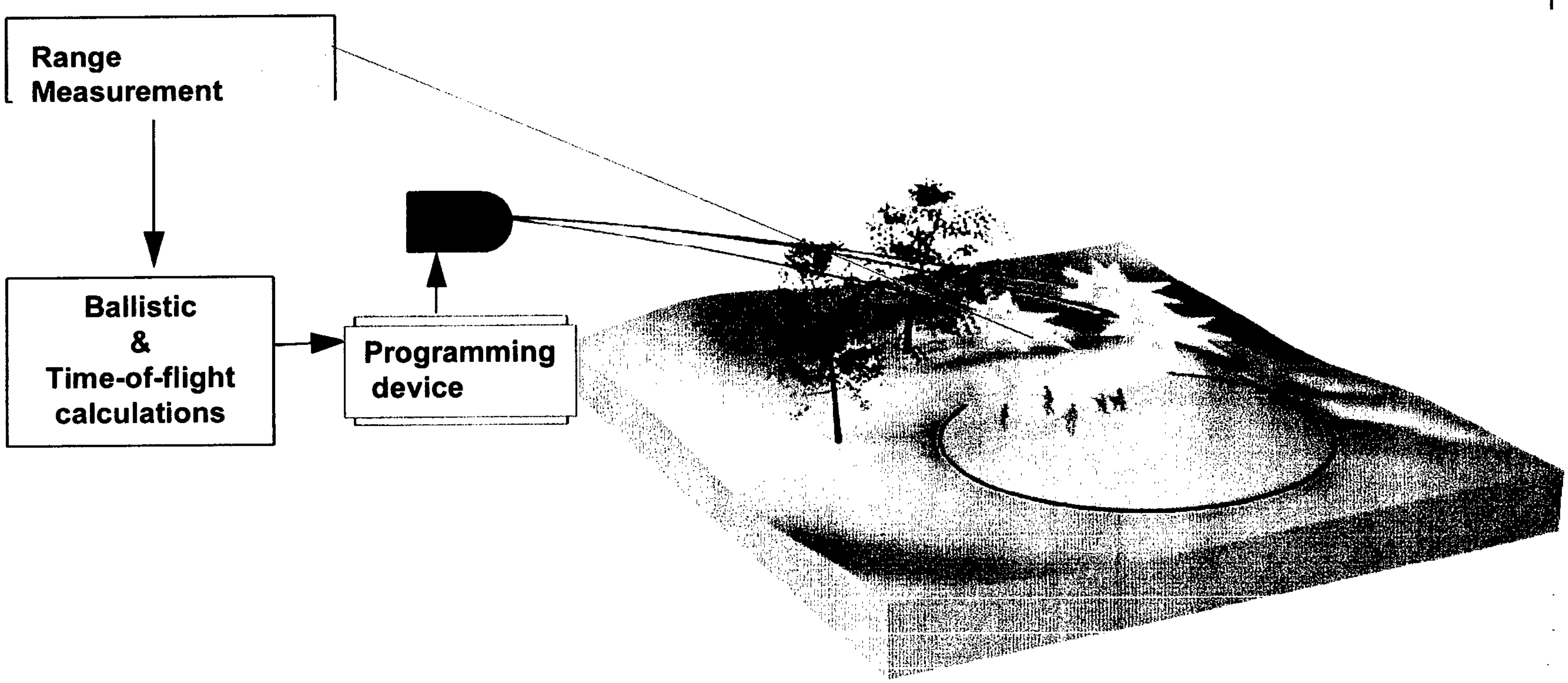
Principle of Air Bursting Ammunition



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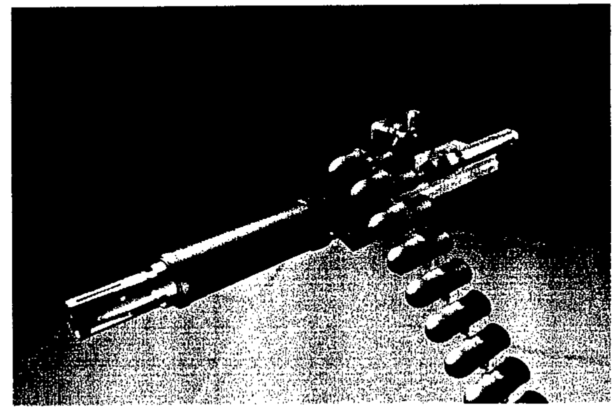
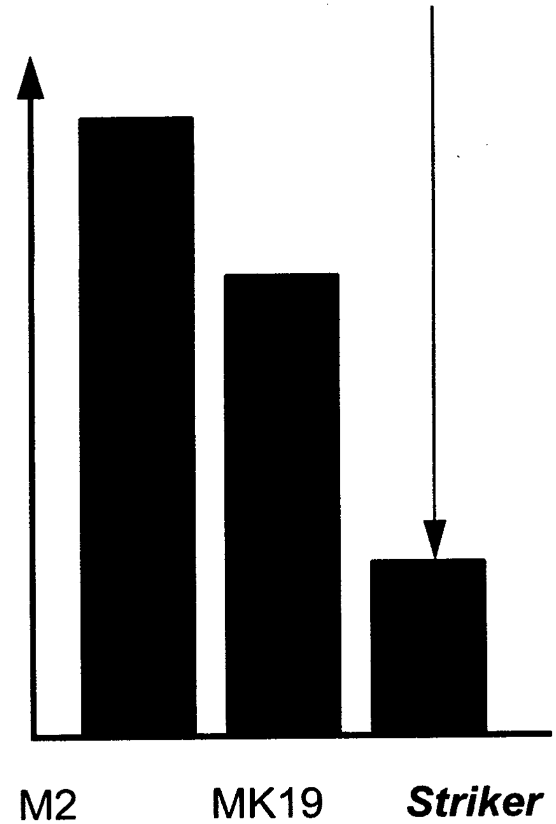
Weapon Design



- Stability & Low Weight
  - Recoiling Mass / Total Gun Mass
  - Internal Hydraulic Soft Mount
- Fires Current DOD and NATO Inventory Ammunition
- Built to fire new BOFORS "Programable" 40mm Ammunition
- Embedded Controls
  - Built for "Soldiers"
- 8 Key Safety Features
- Closed Bolt Firing
  - In Bore Fuzing
  - Lower dispersion

Low Recoil Energy

* Low Recoil Energy = Easy Mounting on Mobility Platforms
* Lower Recoil Energy = Improved Accuracy



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Gun Facts

	STRIKER	MK19
Weight	37 lbs	76 lbs
Barrel Removed	31 lbs	
Rate of Fire	250-300 rpm	325-375 rpm
Length	34.6 in	44.29 in
Quick Detach Barrel	20 in	
Width	7.7 in	8.89
Heigth	7.7 in	8.19 in
Charge Pull	**55 lbs**	**99 lbs**
% Gun/Recoil Mass	55%	22%

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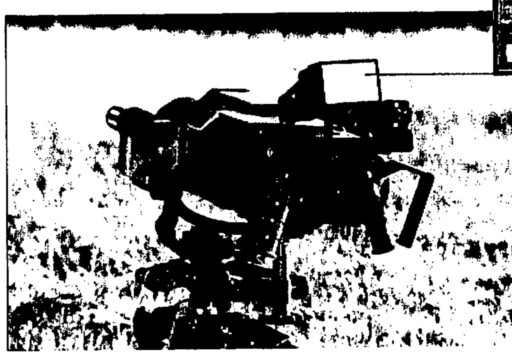
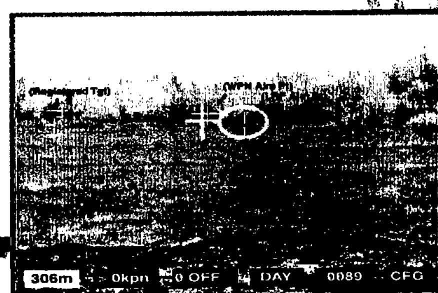
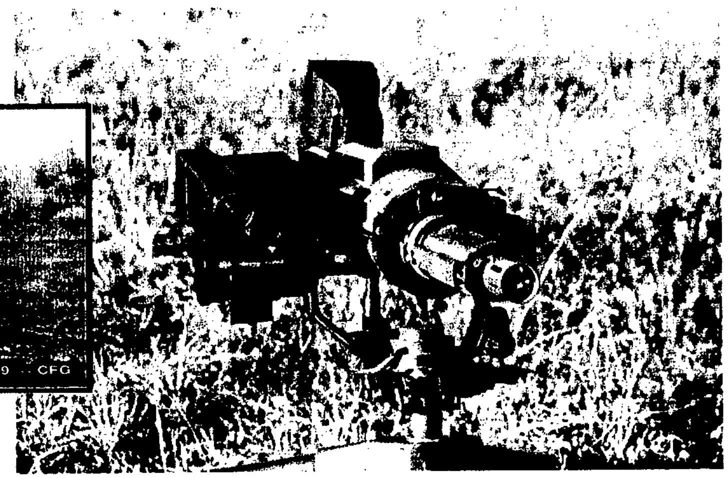
Video Sighting Basics

- Day/night camera + computer + display
- Synchronized Precision electronic mount
- Automatic Aimpoint offset
- Electronic Range Card
- Simplicity for Soldier
  - Laze
  - Aim
  - Shoot







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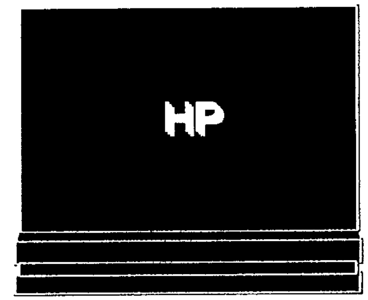
HP Round Features

■ **Prefragmented**	-	**large footprint & high lethality**
■ **Time fuse**	-	**electronic, for air burst**
■ **Point Detonating**	-	**mechanical**
■ **Self Destruct**	-	**electronic**
■ **Safe & arm device**	-	**mechanical** **STANAG distances apply**
■ **Tracer**	-	**w/wo (IR Tracer Option)**
■ **Propulsion system**	-	**off the-shelf** **highly accurate - low muzzle velocity dispersion**
■ **Ballistics**	-	**compatible with M430**
■ **HEDP Version**	- +	**penetration> M430** **behind armour effect**



Multi Spectral Screening "Smoke"

- •Will use BOFORS Fuze
- •MultSpectral Screen
- •Air Burst = Good Screen Material Dispersion
- •Other

The HP round leverages "3P" Fuse Technology

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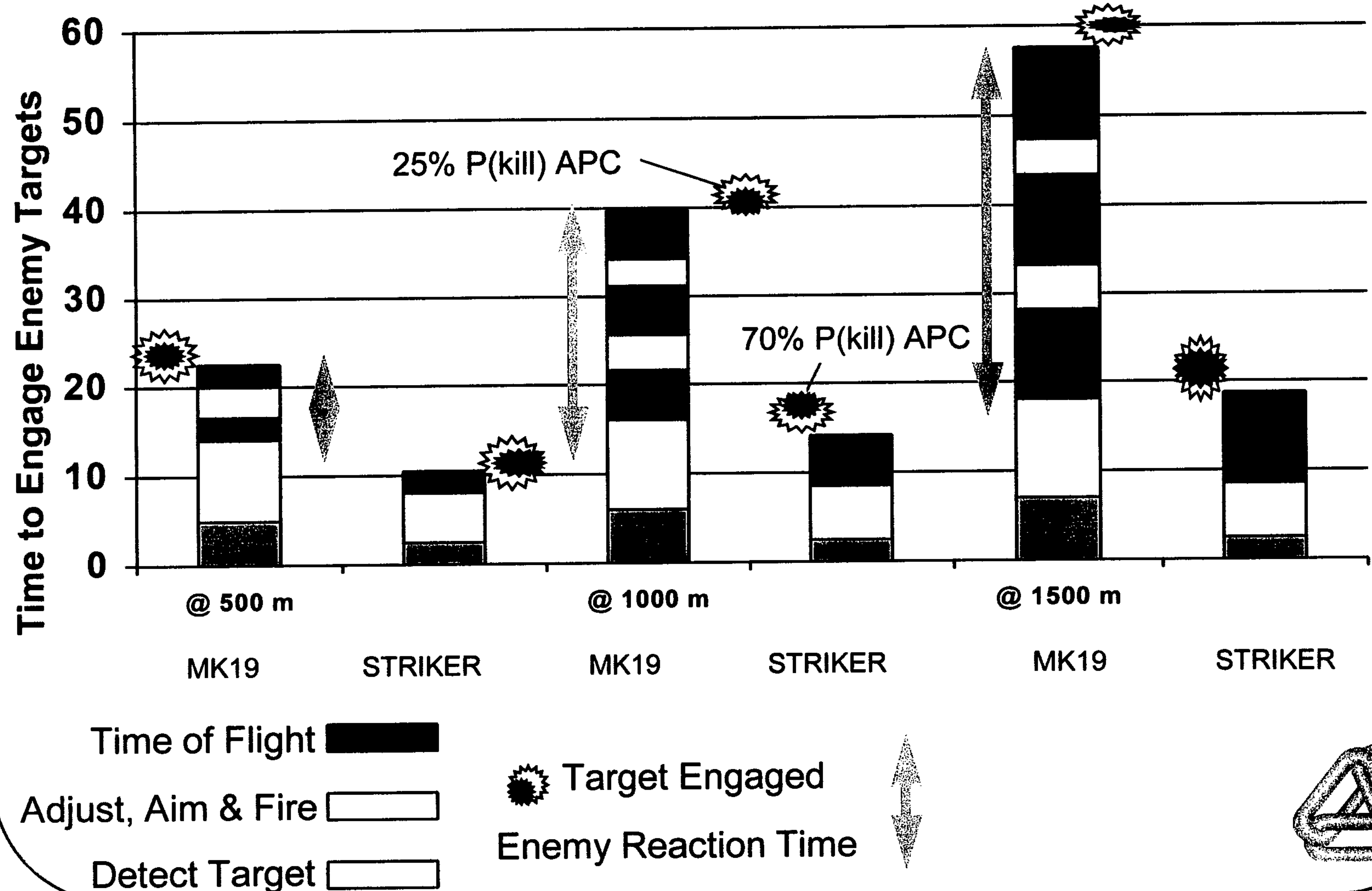
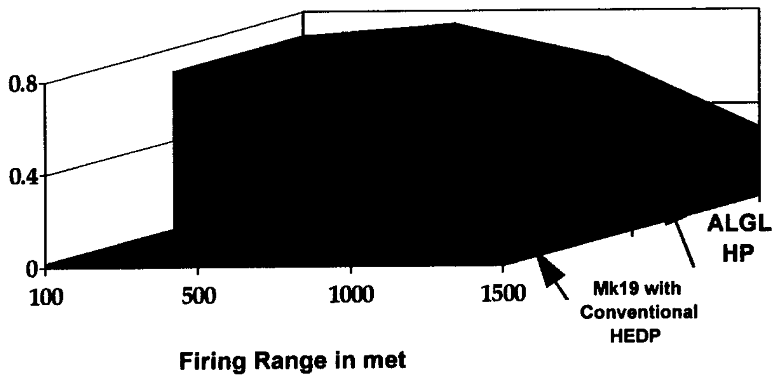
First Burst Destruction



System comparison $P_{incapacitation/hit}$

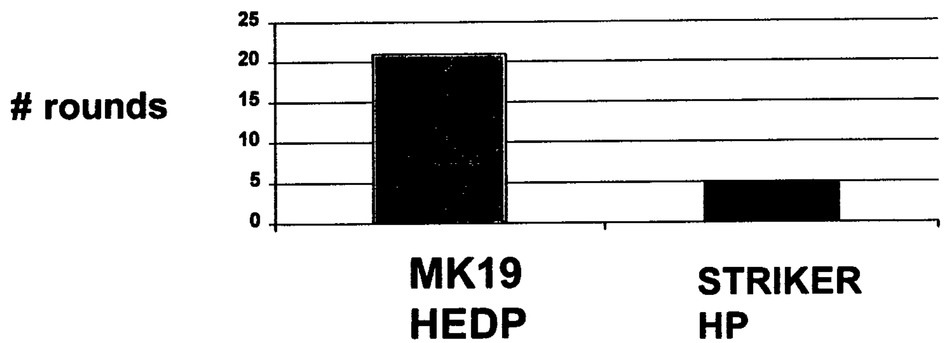


5 Round Burst

Target 10 Standing Soldiers (10 x 20m) area

$P_{incapacitation/hit}$

Mission cost



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Weapon Pay-off

Simplicity

Smart Technology

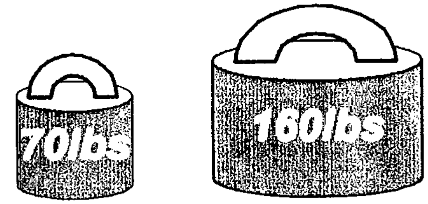
+ Precision

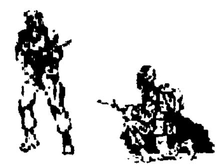
= 75% less ammo/mission

= 60% less gun weight

= 1000% Operational Improvement

More Firepower with Lighter Loads



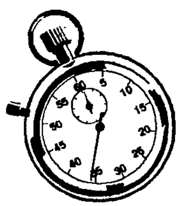


More Mission Capability

More Stowage for Fuel, Water, Food

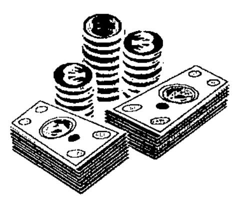
Effective Destruction of Enemy

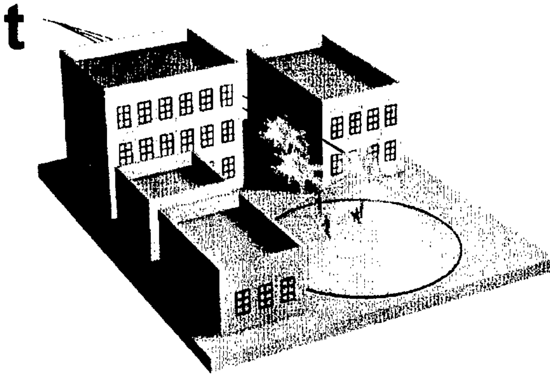
Better Survivability



More Engagements / minute

Lower Costs





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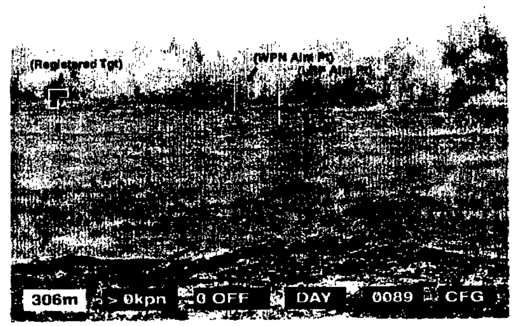
Advanced Weapon & Fire-Control Technology

- **Gun Technology**
  - **Lightweight**
  - **Ready Soldier Controls**
  - **Recoil Reductions**
  - **Embedded Fuzing**
- **Fire Control**
  - **Aids Target Detection**
  - **Adjusted Aim Point**
  - **Sets Fuze**



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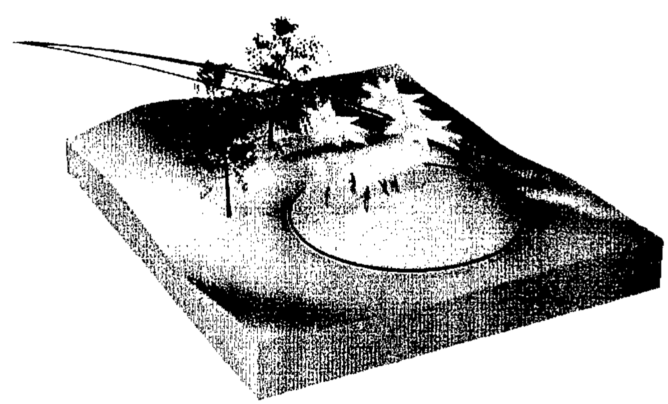
Air-Bursting
Fuse Technology

Conv. HEDP

Lethality Area
of one round
8 vs 100 m^2

HP Air Burst
Footprint

Low Dispersion
Propulsion System



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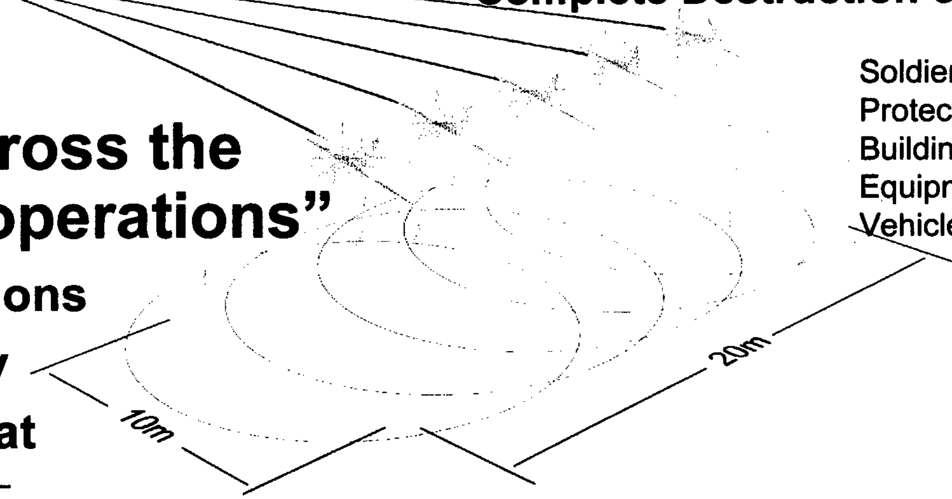
Weapon Missions

- **Firepower for light & mobile units**
- **Protection of Critical Personnel and Mobility Assets**

Complete Destruction of Enemy

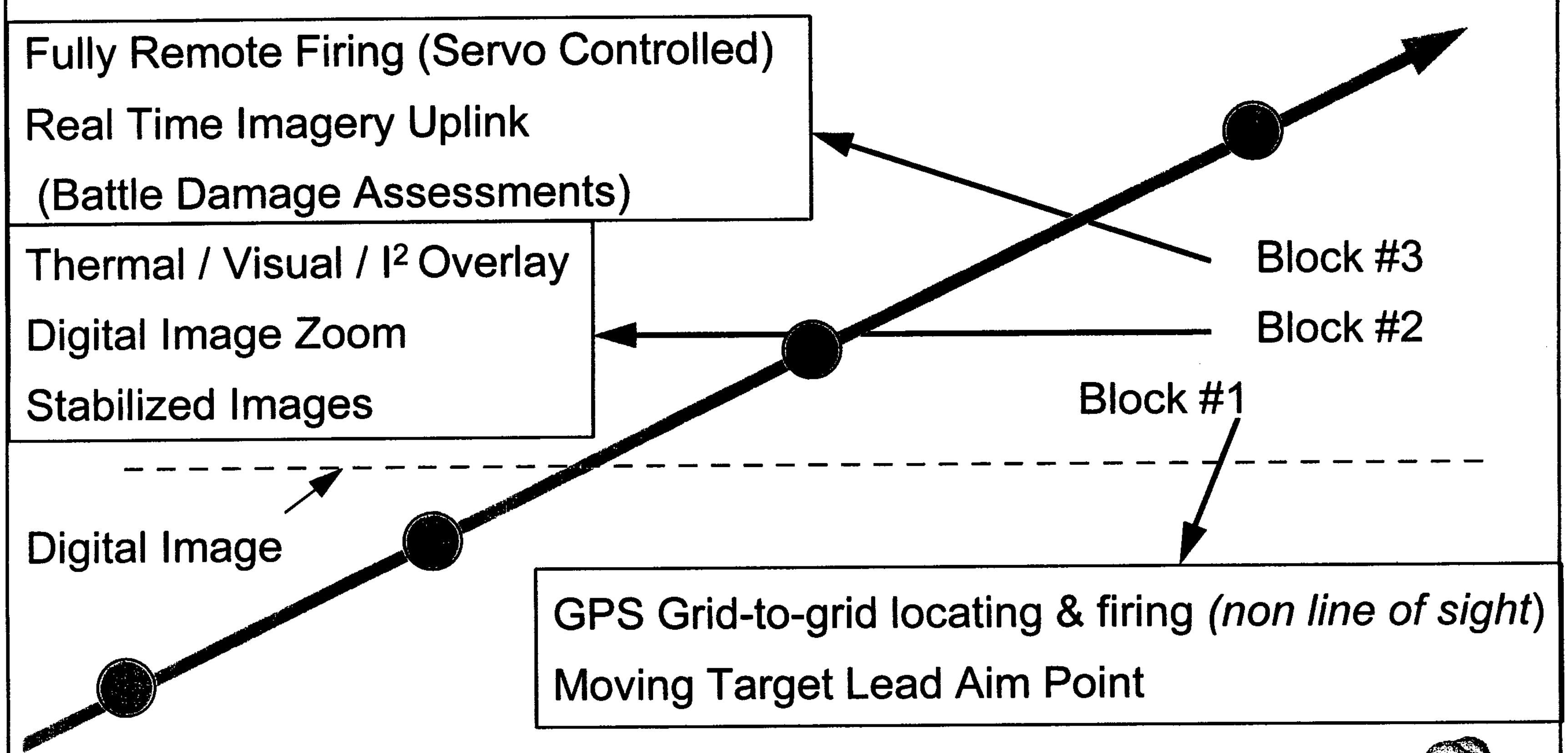


Soldiers & Formations
Protective Bunkers
Buildings
Equipment
Vehicles

- **Effective across the "spectrum of operations"**
  - **Special Missions**
  - **Low Intensity**
  - **Heavy Combat**

SacoDefense incorporated | BOFORS CARL GUSTAF CELSIUS GROUP | Computing Devices Canada

Technological Growth



SacoDefense incorporated

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CELSIUS GROUP

Computing Devices Canada

Summary

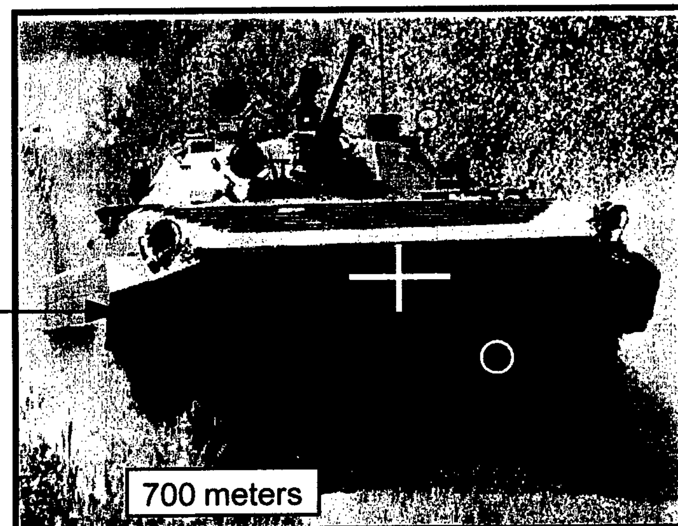
- **Significant Industry Team Investment**
- **3 New Technologies Vastly Enhance**
  - Lethality & Effectiveness
  - Friendly Survivability
  - Target Detection Capability
  - Mission Capability
  - Mission Flexibility

STRIKER 40mm

Smart Weaponry for Warriors

WARNING
Do you want to Delete this Target?

No



DIRECTIONAL INFRARED COUNTERMEASURES - SYSTEM TRADEOFFS

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1. Introduction

In the last ten years infrared (IR) heat-seeking missiles have accounted for the loss of more aircraft than any other battlefield weapon. Currently deployed IR countermeasures (IRCM) systems include flares and active on-board jammers. The deployed active on-board IRCM systems consist of broad-beam jammers. Second and third generation IR missiles have now been deployed with flare rejection circuitry and are less susceptible to IR jamming. Jamming these threats requires higher jamming signal levels that must be projected at all azimuth aspects around the aircraft. Due to these factors, broad-beam IRCM is no longer practical. These factors are the impetus for the development of directive IRCM (DIRCM). A DIRCM system uses a narrow, high-intensity jamming beam that is pointed at the incoming threat.

In comparison to the older, broad-beam IRCM systems, a DIRCM system is much more complex. A DIRCM system must perform the following functions that were not performed in a broad-beam system:

- Detect a missile engaging the aircraft
- Handoff to a fine track sensor
- Track the missile in a clutter background
- Direct a narrow-beam jamming source at the missile.

At the same time as weapon technology advanced, the political environment changed with the fall of the Berlin Wall. As a result, defense budgets were cut, and a new set of priorities emerged from the user environment. No longer were electronic warfare systems developed solely for one platform, thus commonality became a high priority. Upgradeabililty also became important as the end users realized that systems were going to be kept for longer periods of time and threats were going to continue to evolve.

The purpose of this paper is to look at some of the design tradeoffs that are performed when designing a DIRCM system. These design tradeoffs will be illustrated by examining several different hardware implementations of a DIRCM system and how effectively each meets the overall system requirements. Recommendations will be made for the selection of certain hardware approaches to maximize the performance of a DIRCM system.

2. System Design Process

As with any engineered system, the overall system engineering process is crucial to development of a DIRCM system. The design of a DIRCM system must be an iterative process due to the system complexity. We break the general design process down into four main activities:

- Requirements Analysis
- Functional Allocation
- Synthesis/Design
- Technical Assessment and Control

Figure 1 graphically illustrates the relationship between these activities. The main thrust of this paper is a detailed discussion of the synthesis/design of several key DIRCM components. Requirements Analysis, and Functional Allocation will only be covered in enough detail to support the Synthesis/Design discussions. Technical Assessment and Control, as shown in Figure 1, is an integral part of the other three system design components and will not be discussed separately. We begin with an overview of the requirements analysis pertinent to the synthesis/design components discussed in this paper.

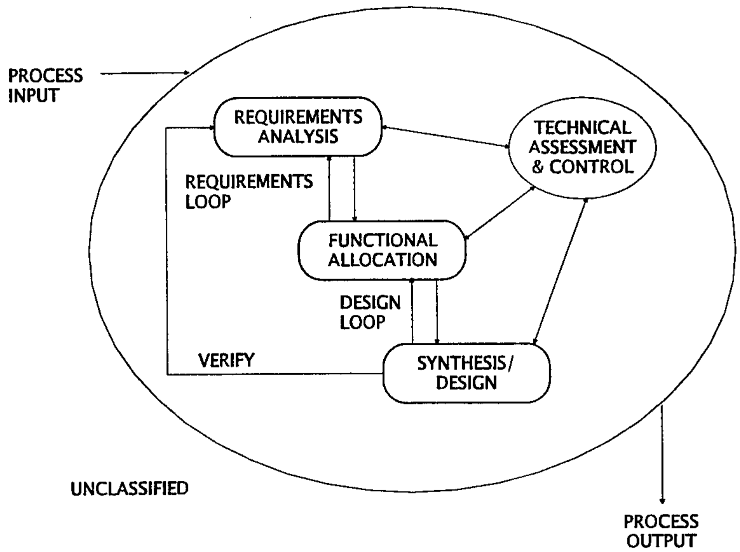


Figure 1: Iterative System Engineering Process

3. Requirements Analysis

The first step in the system design process is requirements analysis. The analysis is conducted iteratively with Functional Allocation and Synthesis/Design in order to refine the requirements as the system definition becomes more detailed. Requirements stated/mandated by the customer are the basis for all other requirements. These requirements can be quite general (for example, a 94% survivability goal for an aircraft against all IR missile attacks) or fairly specific - such as a requiring a minimum jamming signal to aircraft signature ratio (J/S) ≥ 10. Specific customer mandated requirements stem from an a priori knowledge of successful IRCM system requirements.

In order to more clearly assess the system definition, we define five basic types of requirements:

- Functional/Operational requirements
- Performance requirements
- Adaptability requirements
- Constraint requirements
- Availability (ARM) requirements

Functional/Operational requirements describe the tasks a system must perform, general system characteristics necessary for this performance and operating conditions such as normal aircraft mission profile. Performance requirements define what the technical capabilities and parameters of the system must be in order to achieve a specified level of performance (e.g., J/S $\geq$ X). Adaptability requirements define the systems' ability to accommodate new or changing requirements such as the incorporation of alternate jamming sources. Constraint requirements describe mandated factors that limit the design, such as how much power is available from the aircraft. ARM requirements address the ability of the system to perform its required tasks over time without failure and the serviceability of the system. For the purposes of this paper we will discuss some of the basic DIRCM requirements relating to three of these categories: Functional/Operational, Performance and Constraint.

3.1 Functional/Operational Requirements

An IRCM system of any kind has one overall requirement: defeat an IR missile threat. For a DIRCM system in particular we can break this overall requirement into four basic functional requirements:

- Acquire the missile threat
- Track the approaching missile
- Direct countermeasure energy at the missile
- Defeat the missile threat.

3.2 Performance Requirements

One of the key performance criteria for any system is how well it must work. The customer understands that it is usually not practical to design a system to be 100% effective and meet the rest of the system constraint requirements such as cost, weight and power. Typically the customer defines a level of survivability or protection that the system must be designed to, such as defeating 94% of the threats. The survivability requirement has profound impact on the design of the system.

General system performance requirements such as this are usually broken down into more specific allocated requirements to a specific set of hardware subsystems. More specific derived requirements are then produced for the hardware subsystems based upon the allocated requirements. We will show in section 4 how an overall system performance probability requirement such as this can be broken into a set of allocated, derived requirements. An analysis of these derived requirements in relation to cost and risk of the final product will reveal whether the overall goal is practical.

3.3 Constraint Requirements

An IRCM system must have a minimal impact on aircraft performance. When this requirement is combined with an emphasis on commonality, such that the system can be installed on more than one aircraft, several key constraint requirements are derived. Some of these constraint requirements include system weight, power and size. Less obvious is a requirement for installation orientation. This requirement flows from that fact that a DIRCM system will typically be installed in an aircraft already designed and in service. The system line replaceable units (LRUs) must be capable of being mounted in whatever installation space is available. When more than one space is available, the guiding principle is to select an installation that provides the optimum unobscured field of regard (FOR) for the DIRCM subassemblies. If a DIRCM hardware design had an orientation limitation, it would significantly curtail its commonality to multiple platforms.

4. Functional Allocation

Once we have identified the functional requirements, we can begin to allocate these requirements among various subsystems by postulating various point-design approaches. It is important to remember that this is an iterative process. Functional allocation begins with the four functional requirements outlined in section 3.1. An overall system performance requirement must be allocated to these functional requirements. As an example, we will use a customer defined survivability requirement of 94% to illustrate an example of functional allocation and its interrelation with requirements analysis and synthesis/design.

4.1 Number of Components

First of all, our requirements analysis has pointed out four main functions the system must perform when defeating the threat. We must also take into account the availability of the system when computing the probability of defeating a threat. Therefore, the system performance requirement must be allocated among five functions instead of four. Each of the system functions is necessary and independent. Therefore the overall system performance probability is the product of probability of each function working correctly[1]. In the first iteration of synthesis/design we find that it may be necessary - under cost, risk and adaptability requirements - to allocate the acquisition and tracking functions into a missile warning system (MWS) and a higher resolution fine-track sensor (FTS), respectively. In the second iteration of requirements analysis, we note that this new system configuration option requires a new functional/operational requirement: handover of the threat from the MWS to the FTS. Furthermore, we can foresee that other system configuration options may require even more functions.

We can allocate an individual function performance probability requirement from the system performance requirement if we assume that all components have an equal probability requirement. During subsequent iterations of the design process, the performance level of an individual function may be traded off in order to achieve the overall system performance, but equal performance is a reasonable assumption for the first few iterations.

The required performance probability of each function (P_{comp}), under the assumption that all components have equal performance, will be:

$$P_{comp}\left(N_{comp}, P_{sys}\right) = \sqrt[N_{comp}]{P_{sys}} \quad (1)$$

where N_{comp} is the number of functions and P_{sys} is the desired system performance (or survivability).

In order to take into account the reliability of the missile without any countermeasures we can introduce the effective system performance (P_{sys_eff}),

$$P_{sys\_eff}\left(P_{missile}\right) = 1 - \frac{1 - P_{sys}}{P_{missile}} \quad (2)$$

where $P_{missile}$ is the reliability of the missile.

Using the effective system performance from equation 2 in equation 1, we can calculate the required function performance for a given number of functions, system survivability and missile reliability. Figure 2 shows plots of the function performance required for different numbers of functions at 100% and 75% missile reliability and a 94% system survivability.

We note from Figure 2 that each function can have a lower performance when there are fewer functions the system must perform. As part of the synthesis/design process, the system designer tries to minimize the number of independent functions the system must perform to keep the functional probability requirements at a practical level. However, Figure 2 also illustrates that even for the six DIRCM functions, the probability requirements for an individual function are 98.6%. If the hardware that performs these functions has some random performance variables associated with its performance, it must be designed to operate correctly under 3 sigma variation conditions[2].

[1] One could argue that these function will not necessarily be independent. For example, a long-range threat that is difficult for the MWS to detect will also be difficult for the system to track. However, if the system functions have a high-performance probability requirement, there will be a smaller chance that the system functions are related.

[2] The actual design point is slightly less than 3 sigma and depends upon whether the distribution is one or two dimensional. For the sake of simplicity, we will use a design goal of 3 sigma in this paper.

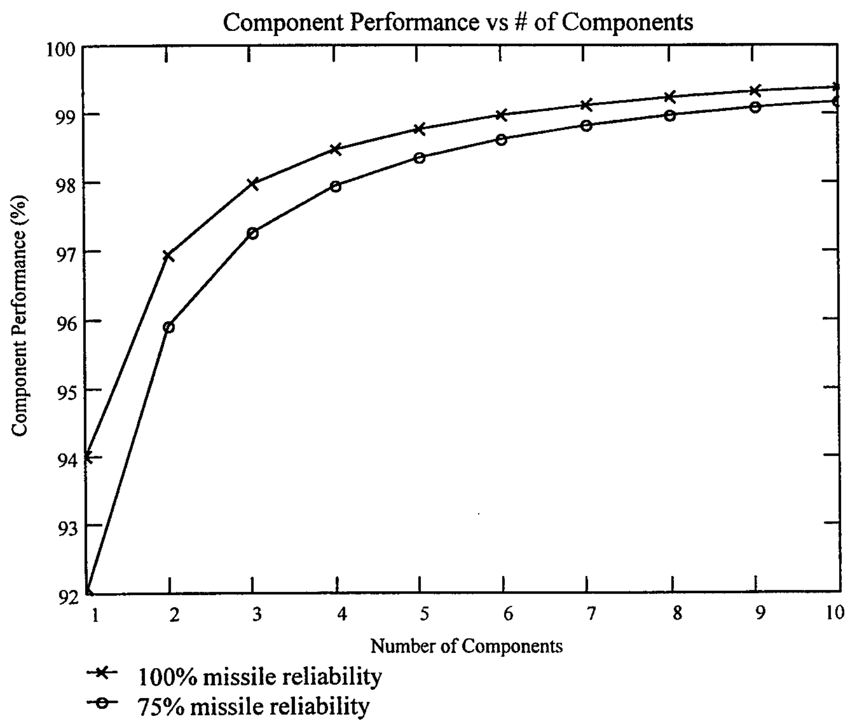


Figure 2: Required function performance versus the number of functions in order to achieve a 94% system survivability.

We note that the 98.6% example component performance is ambitious but achievable. This requirement will be a primary driver in the functional allocation of subsystem requirements and hardware selection. We can identify some general requirements of the system, based on the high performance requirements noted, that will be pertinent in subsystem functional allocation.

- The system must be able to acquire and track missile threats at their maximum range.
- The system must be able to track missiles in their post burnout (PBO) stage.
- The system must be able to acquire and track missiles launched from almost every angle for which the threat is capable.
- The system must have a rapid response time to counter short shots.
- The system must not experience reduced performance under conditions of normal and extreme own ship motions.
- The system must be capable of pointing narrow jamming beams/laser sources under normal and extreme vibration environments.

4.2 Subsystem Definition

The basic functional requirements can now be allocated to hardware-specific subsystems. This functional allocation is illustrated in Table 1. This functional allocation is straightforward but not unique. In this allocation, missile acquisition and missile tracking have been allocated to two subsystems, an MWS and an FTS. One could propose to allocate these functions to one hardware subsystem such as a large field of regard, high angular accuracy MWS. However, a large field of regard and high angular accuracy is difficult to achieve in one sensor. With this initial allocation process, more specific hardware requirements can be derived.

Table 1. Hardware Allocation of Key Functional Requirements

FUNCTIONAL REQUIREMENT	HARDWARE ALLOCATION
Acquire the missile threat	MWS
Handoff from the MWS to the FTS	MWS/FTS/and Pointing System
Track the missile	FTS
Direct countermeasures at the threat	Pointing System
Defeat the threat	Jamming Source

4.2.1 MWS Requirement Flowdown

The first step in the operation of a DIRCM system, as pointed out in section 3.1, is to acquire any IR missile threats to the aircraft. This is the primary role of the MWS subsystem. Some of the critical parameters of an MWS subsystem are:

- Field of regard (FOR)
- Angle of Arrival (AOA) accuracy
- Resolution
- Update rate
- Sensitivity
- Warning Time
- False Alarm Rate.

During the normal system engineering process, the requirements above are more fully defined based upon the overall functional requirement of detecting 98.6% of the threats. For the purposes of this paper, we will discuss only two requirements - the AOA accuracy and the system resolution.

The AOA accuracy defines the accuracy with which a threat can be located in the MWS FOR. The resolution defines the minimum angular separation between two sources necessary for the system to distinguish them. Figure 3 gives a graphical definition of AOA accuracy and resolution. Obviously, if an MWS has better resolution, it will be able to detect threats better in a high clutter environment. A more accurate MWS will allow other components of the DIRCM system to have more tolerance in their design. We will not derive a fixed requirement for the MWS AOA accuracy and resolution at this point since a DIRCM system can be designed to accommodate various MWS AOA accuracies and resolutions. As will be shown in Section 5, there is a direct relationship between MWS accuracy and resolution and the FTS field of view through the handoff requirement.

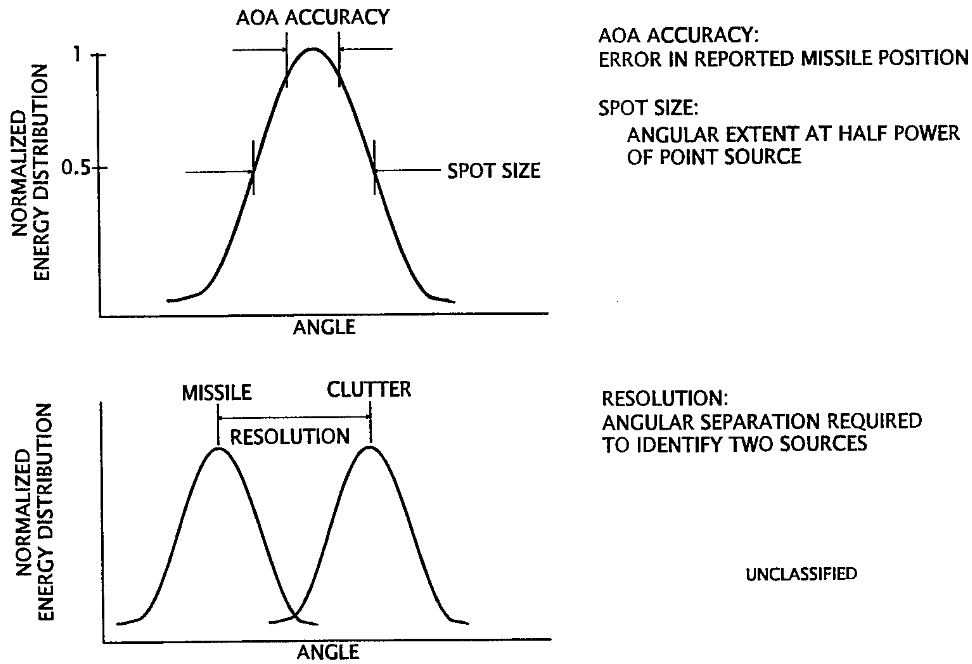


Figure 3: AOA accuracy and resolution definitions.

4.2.2 FTS Requirement Flowdown

In order to effectively track a missile and apply jamming energy on the threat, a DIRCM system requires accurate, high resolution information about the threat's position, updated at a high rate. The critical parameters of an FTS subsystem are the similar to those of the MWS sensor:

- Field of View
- Angular track accuracy
- Resolution
- Update rate
- Sensitivity
- Spectral region of operation

This paper will not derive specific requirements for the FTS but will instead try to show how the requirements for the FTS and the MWS interact and must be traded off in the synthesis/design process. However, some general comments can be made about the FTS requirements. The FOV of the FTS needs to be kept as small as possible. A smaller FTS FOV will increase the tracking accuracy, resolution and sensitivity. Each of these features will enhance system performance, improve the tracking probability of long range threats, and make the system easier to upgrade to point new sources.

In general, the FTS tracking accuracy requirement will be determined by the pointing requirements of the system. Typical laser beamwidths are on the order of a few milliradians. These laser beams must be pointed with an accuracy of 1/4 to 1/8 of the beamwidth to maintain a high J/S during the missile engagement. To achieve this pointing accuracy, the track accuracy of the system needs to be approximately 1/5 to 1/10 of the pointing accuracy. Thus the track accuracy will need to be approximately 1/20 to 1/80 of the laser beamwidth. The update rate of the FTS will also have a strong impact on how well the system points due to the large line of sight rates and accelerations encountered when tracking a missile.

4.2.3 Pointing Subsystem Flowdown

Fundamental to any DIRCM system is the pointing subsystem. The central premise of directional countermeasures is the ability to provide greater jamming energy on the threat through the use of a directional beam that is actively pointed at the threat. The capabilities of the pointing subsystem, therefore, are crucial to the ability of the system as a whole to meet its performance requirements. The critical parameters of a pointing subsystem are:

- FOR
- Slew and Settle Time
- Pointing Accuracy
- Stabilization

The overall system FOR requirement may be met with one or more pointing subsystems. From the standpoint of cost and multiplatform capability, a larger pointing subsystem FOR is preferable. A large subsystem FOR reduces the need for multiple pointing systems on a platform in order to meet the overall platform's FOR requirements. This is particularly important since the pointing system will be one of the most costly DIRCM components. Since the pointing system must cope with variations in mounting positions, platform ownship motion and attitude as well as obscuration by various aircraft parts, it will generally need an intrinsic (neglecting obscurations from the aircraft) FOR greater than a hemisphere. The pointing accuracy and stability requirements must be sufficient over this FOR to point a narrow laser beam with a beam width of a few milliradians in the presence of platform ownship motion and vibration.

4.2.4 Jamming Source Subsystem Flowdown

The jamming source provides the optical IR energy to the pointing system to jam the threat. This IR energy is modulated in a waveform designed to defeat one or a variety of threats. Narrow lamp beams provide all band coverage of the various missile operating bands. Laser jamming sources typically operate at one threat waveband; however, solid state lasers have been developed to operate over all three major IR missile bands. The critical performance parameters for the jamming source are:

- Peak and average radiant intensity
- Beamwidth
- Spectral coverage
- Modulation flexibility
- Depth of modulation
- Sustained jamming time
- Source life.

5. Synthesis/Design

Now that we have discussed the requirements for the key subsystems, we can consider the tradeoffs involved in choosing various hardware approaches to implement these requirements.

5.1 Design Philosophy

First of all, the overall philosophy of the hardware tradeoff decision making process should be decided upon. There are two basic philosophies that will be appropriate under different circumstances. The first philosophy is low risk. A low-risk philosophy may be mandated by the customer. This philosophy is appropriate when production hardware is being designed to meet a hard delivery schedule and tight cost containment is a high priority. Low-risk hardware tradeoff decisions will favor a conservative approach. The second philosophy is high capability. Although risk reduction should always be an important goal, a system with a long delivery schedule and less cost containment constraints may be better served by allowing some riskier design decisions and technologies to be incorporated. For this paper we will utilize a low-risk design philosophy that examines tradeoffs using low-risk, proven technology.

5.2 Hardware Tradeoffs

We will now discuss some of the hardware-related tradeoffs that must be addressed in order to achieve the allocated requirements for the MWS, FTS, pointing and jamming source subsystems.

5.2.1 MWS Hardware Tradeoffs

MWS technologies can be either active or passive. Active systems such as radar are attractive for their ability to locate and track an incoming missile independent of the missile's emanations. Their primary disadvantages are that they are radiation emitters themselves and they have poor AOA accuracy. Because of their emissions and AOA accuracy, active systems are not candidates for the MWS. We propose here three MWS design approaches and tradeoffs and how each type will impact the FTS FOV requirement. Each of these systems is low risk and readily deployable and with proper design each can meet the basic MWS requirements. The three postulated designs are:

- Low resolution EO
- High resolution, high accuracy EO
- Scanning IR sensor.

EO sensors have the advantage that they are relatively small, light and do not require cooling. Their main disadvantage is that EO sensors utilize ultraviolet radiation which is scattered strongly by the atmosphere limiting AOA accuracy to a fraction of a degree. EO sensor performance can also be reduced by atmospheric ozone effects that do not limit the missile performance. Several EO MWS sensors have been deployed and the technology can now be considered relatively mature. The low resolution EO design approach utilizes a small detector array and achieves its AOA accuracy by blurring the image spot on the array and centroiding to find the pixel center. This blurring approach improves AOA accuracy; however, sensitivity and resolution are reduced. The high resolution EO MWS utilizes a higher resolution detector array and therefore has a higher acquisition cost and requires more processing than the low resolution EO sensor.

IR radiation is not scattered as strongly as ultraviolet radiation, and therefore IR sensors can have better AOA accuracy and relatively good performance in most atmospheric conditions. They operate in the same wavebands as the missiles so when the IR MWS performance is hindered by weather, the missile performance will also be hindered. Their primary disadvantage is that they require cooling to achieve high sensitivity. The cooling system must generally be mechanical, which impacts the reliability of the system. In addition, the cool down time of the sensor adversely impacts the system readiness. There are also greater clutter problems in the infrared when compared to the EO MWS. The IR sensor proposed here is based upon a scanning linear detector array similar to many common IR search and track systems (IRST). A drawback of this system is the low update rate on threat position since the system is scanning.

Nominal characteristics of each type of sensor are listed in Table 2 based upon engineering estimates. As shown in this table, the primary advantage of the low resolution EO sensor is cost - due to reduced detector resolution and processing power. The primary advantage of the high resolution EO sensor is obviously its accuracy and resolution. The advantage of the IR sensor is detection range and insensitivity to many environmental conditions as well as excellent resolution and accuracy.

Table 2. Characteristics of Proposed MWS Approaches

DESIGN PERFORMANCE CONSIDERATION	LOW RESOLUTION EO	HIGH RESOLUTION EO	SCANNING IR
Detection Sensitivity	Fair - will require large optics	Good	Excellent - Insensitive to Environment
Nominal AOA Accuracy	Medium	Fine	Extra Fine
Nominal Resolution	Poor	Fair	Good
Update Rate	Medium	High	Low
Initial Acquisition Cost	Low	Medium	Medium
Life Cycle Cost	Low - no moving parts	Low - no moving parts	High - Cooling Required

We will now consider how the MWS sensor's parameters effect the FTS FOV. Figure 4 defines the FTS FOV requirement given the MWS AOA accuracy and resolution in the presence of an unresolved clutter source. Assuming the clutter source separation from the missile is a uniform random variable from the coincident location (no separation) to the resolution of the MWS sensor, we see that the average error magnitude will be $\Delta/4$ where Δ is the resolution of the sensor. Thus the FTS FOV requirement will be proportional to: $2*(\Delta/4)$. Figure 4 also shows that the FTS FOV requirement is proportional to approximately six times the MWS AOA accuracy. A factor of three occurs since the AOA accuracy is usually reported as an RMS error and we must design the system to work at the 3 sigma point and a factor of 2 occurs due to the fact that we do not know the direction of the error.

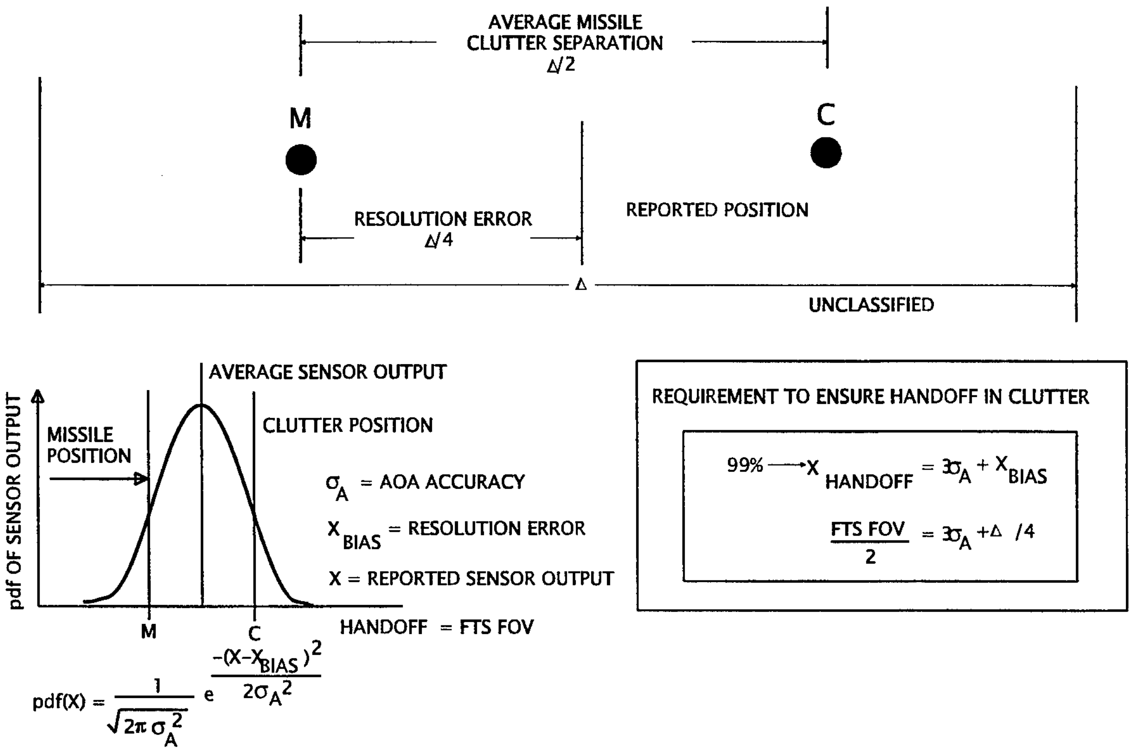


Figure 4: FTS FOV defined in terms of MWS AOA accuracy and resolution for a situation that includes an unresolved clutter source.

Other factors must be considered when calculating the FTS FOV to achieve greater than a 98.6% handoff probability. These other factors include parallax errors caused by the MWS and the FTS being displaced on the aircraft, latency caused by the MWS update rate and missile motions, and static misalignments. Table 3 presents the major sources contributors to the FTS FOV handoff error budget and an estimate of the error type and significance of the error. This table shows that the major random error besides the MWS AOA accuracy is the error produced from aircraft flexure and vibration. The FTS FOV requirement is determined by the following formula:

$$\text{FTS FOV} = 2 * [(3*\text{RSS of the Random Errors}) + \text{Bias Errors}]. \qquad (3)$$

The factor of 3 is required to insure that handoff occurs with a greater than 98% probability. Based on Equation 3 the FTS FOV requirements can be calculated for each of the MWS approaches and the general magnitude of the FOVs is listed in Table 4.

Table 3. Angular Error Sources Contributing to FTS FOV Requirement

ERROR SOURCE	TYPE	MAGNITUDE	SOURCE
AOA Accuracy	Random	MWS Dependent	Engineering Estimate
Aircraft Flexure Error	Random	Significant	Aircraft Manufacturers
Transmitter Settling Error	Random	Insignificant	Engineering Estimate
Resolution Induced Error	Bias	MWS Dependent	Engineering Estimate

Parallax Correction Error	Bias	Significant	Engineering Estimate - Installation Dependent
MWS/Transmitter misalignment	Bias	Significant	Aircraft Manufacturers
Missile Motion Errors	Bias	MWS Dependent	Analysis based on missile rates

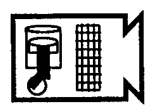
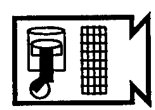
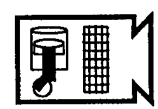
Table 4. FTS FOV Requirements for Each MWS Approach

MWS DESIGN APPROACH	REQUIRED FTS FOV
Low Resolution EO	Big
High Resolution EO	Medium
Scanning IR	Medium

5.2.2 FTS Hardware Tradeoffs

Since the FOV of the FTS was determined by our MWS requirements and since it must be an IR sensor for PBO missile tracking, the primary hardware tradeoff issues deal with the type of detector array. In this section we will examine several detector array options for the FTS as shown in Table 5. Each of these array choices is readily available and low risk[3].

Table 5. FTS Detector Array Options

DESIGN PERFORMANCE CONSIDERATION	 TE Cooled HeCdTe	 Cryo Cooled HeCdTe	 Cryo Cooled PtSi	 Cryo Cooled InSb
Array Sizes	up to 128x128	up to 256x256	up to 512x512	up to 512x512
Sensitivity	Low	High	Medium	High
PBO Tracking	No	Yes	No	Yes
Cool Down Time	Fair	Good	Poor	Poor
Initial Cost	Med	Med	Low	Med
Life Cycle Cost	Low	Med	Med	High
MTBF	Med - requires fan	Med - cryo cooler at >77°K	Low - cryo cooler at 77°K	Low - cryo cooler at 77°K

One of the first features to be examined is the number of detector elements. Detector arrays are readily available in square sizes up to 512 by 512 pixels. More elements in the array will increase the instantaneous field of view of the FTS and improve its track accuracy, sensitivity and resolution. However, the detector and processing costs increase with array size. The minimum acceptable array size is determined by the tracking accuracy requirement and the FTS FOV. Tracking accuracy is primarily a function of the instantaneous field of view (IFOV) of the array. If the optical designer slightly blurs the image on the focal plane array, centroid tracking will achieve an accuracy on the order of 1/10 of the IFOV[4]. The track accuracy is thus given by:

[3] We have intentionally not listed, due to cost and risk, detector arrays that contain a smaller detector pitch at the center of the array and a larger detector pitch on the outside. We also do not discuss the possibility of using costly zoom optics in the FTS design.

[4] Blurring out the optical image improves the track accuracy at the expense of the FTS sensitivity, which is another factor that must be considered.

$$\text{Track Accuracy} = \text{FTS FOV/(array linear size)/10.} \qquad (4)$$

Equation 4 can be solved for the array size as a function of the FTS FOV.

$$\text{Array linear size} = \text{FTS FOV/Track Accuacy/10} \qquad (5)$$

The FOV of the FTS for each MWS approach was discussed in section 5.2.1. Based upon equation 5 we can now discuss the array size for each MWS approach (see Table 6). As shown in Table 4, the low resolution MWS requires a large FOV and it will require a large detector array. If the resolution of the low resolution EO MWS is poor enough, the detector array size requirements get larger than 512x512 making the low resolution MWS impractical. Now we can see the importance of having an MWS with reasonable accuracy and resolution. To use a smaller detector array requires an accurate MWS with reasonable resolution.

Table 6. Detector Array Sizes versus MWS Approaches

MWS APPROACH	FTS FOV REQUIREMENT	DETECTOR ARRAY REQUIRED
Low Resolution EO	Big	Large
High Resolution EO	Medium	Medium
Scanning IR	Medium	Medium

The other major determination for the FTS is the detector material and cooling. In order to fully address this issue, an analysis would have to be performed to determine if each array and the associated optics would be able to accurately track the worst case missile in a clutter environment. The worst case missile signature would naturally be caused by a long range missile in PBO. During PBO a missile motor has burned out and the tracker has to track hot parts on the missile body. This requires a very sensitive FTS since the missile is in proportional navigation and presents a small cross sectional viewing area to the tracker. This paper will not go into this tracking analysis; however, some general comments will be made about detector material and cooling.

The detectivity of PtSi is an order of magnitude lower than HeCdTe or InSb, and would typically require large optical elements to provide enough gain to track long range threats in PBO. HeCdTe has the distinct advantage of a relatively high operating temperature (117°K) compared to InSb (77°K). It can even be operated at temperatures as high as 175°K, allowing thermoelectric cooling. However, when thermoelectrically cooled its detectivity is reduced by 2 orders of magnitude. Thus, a thermoelectrically cooled HgCdTe array would also probably be impractical due to the large optical elements required for PBO missile tracking. Based upon the PBO tracking requirement, cryo cooling is probably required. Both InSb and HgCdTe can be cryo-cooled yielding high sensitivity. HgCdTe has the distinct advantage that the operating temperature can be raised above 77°K to the point where the minimum FTS sensitivity is achieved. This will extend the life of the cryo cooler and reduce cool down time.

5.2.3 Pointing Subsystem Hardware Tradeoffs

The pointing subsystem can have a variety of designs in order to achieve the required pointing accuracy, FOR, slew & settle time, and stabilization. The most fundamental tradeoff for this subsystem is how many degrees of freedom it should have. The one, two and a three (or four) degree of freedom (DOF) possibilities are shown schematically in Figure 5.

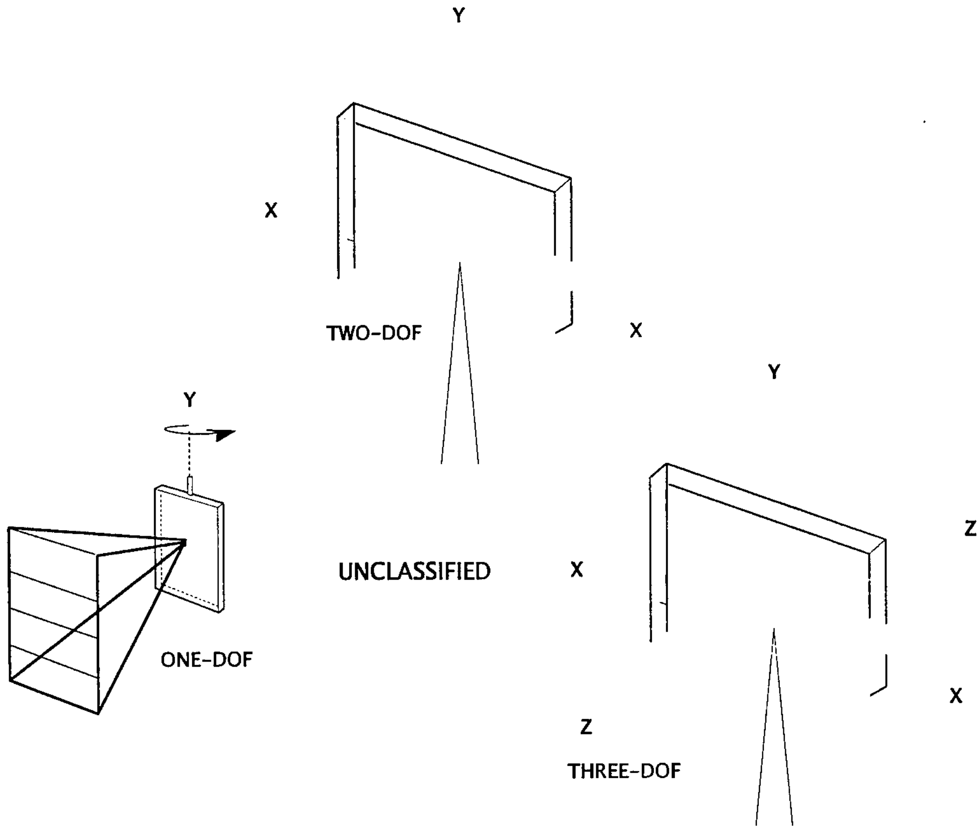
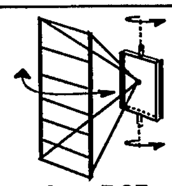
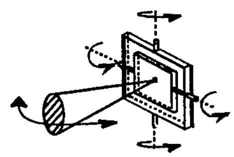
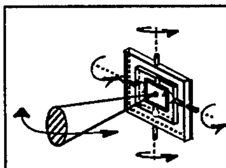


Figure 5: The one, two and three degree of freedom pointing system options.

The characteristics of each of these systems are summarized in Table 7. We have already stated that we need to point a narrow jamming beam in order to produce a practical DIRCM system. Thus the one DOF configuration is rejected. At first glance, it may seem that the two DOF system is ideal as it can point anywhere in the field of regard and is considerably less complex and costly than the three degree of freedom configuration. The problem with the 2 DOF design is that one cannot stabilize the jamming beam or FTS image within a 10 - 15 degree angle off nadir. This represents a large area of unprotected coverage. The only alternative is to limit the mounting of the 2 DOF system such that nadir is always straight up or straight down where IR missiles typically do not engage. Even this mounting is not effective if the host platform exercises moderate own ship motions. The two degree mounting constraints prove to be a severe limitation when trying to mount the system on several different platforms.

In addition to achieving a large FOR, there is a strong engineering reason for the use of a 3 (or 4) DOF system. Stabilization of the entire pointing system in a 2 DOF scheme will require high torque, high bandwidth motors to counter vibration, wind torque and own ship motion effects. These motors must not only move a large mass quickly, but they must move it against the high friction created by the weathertight seals that will be required on the pointing system housing in order to protect the delicate optics and electronics inside. A 3 DOF system, in contrast, can be implemented with a two-axis, course outer gimbal with the full FOR motion capabilities and a small, internal, two-axis inner gimbal with a very small range of motion (just enough to provide stabilization and correction of the outer gimbals pointing errors). The inner gimbal is protected from the elements and can have very low friction movement. The inner gimbal need only move a small mass, perhaps only one mirror, and can have lightweight, low torque motors. This will greatly simplify the task of stabilization and will actually improve the reliability of the overall pointing subsystem over the 2 DOF configuration.

Table 7. Characteristics of Pointing Subsystem Approaches

DESIGN PERFORMANCE CONSIDERATION	 One - DOF Single Axis	 Two - DOF Dual Axis	 Three - DOF Four Axis
Laser Pointing	No	Yes -except at nadir	Yes
Operation near Nadir	No - beam does not cover nadir	No - gimbal lock	Yes
Unconstrained Mount	No - beam must be aligned to AC Signature	No - nadir must be pointed up or down	Yes
Initial Cost	Low	Med	High
Life Cycle Cost	Low	High - large mass to move and position accurately	Med - inner gimbal reduces wear on outer gimbal
MTBF	High	Med - large servos and fine control	High - fine control mirror not exposed to elements

5.2.4 Source Packaging and Beam Delivery

The final tradeoff discussed in this paper concerns delivery of laser jamming energy to the pointing subsystem. Several design approaches can be considered, and they are dependent upon the laser source technology. One approach would integrate the laser into or onto the pointing system. The other approach is to have a separate subassembly for the laser and pipe this energy to the pointing subsystems. The piping can be performed using fiber optics or a free space coupled link. The characteristics of each of these approaches is summarized in Table 8.

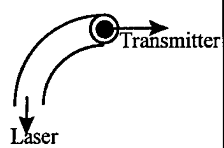
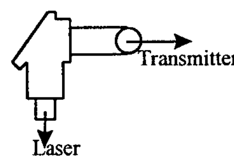
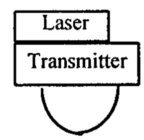
There are several advantages for having a separate subassembly for the laser. Using this approach, one laser could be used to supply the jamming energy for several pointing systems. The optical power could actually be switched from one pointing subsystem to another depending on the engagement angle of the approaching threat. This is especially true if the laser source is expensive and one source provides sufficient power for multiple pointing systems. This approach also provides more freedom for the laser design since it can be mounted away from the pointing system in an internal compartment with more room.

There are several disadvantages and technical challenges to the laser piping approach. The primary technical challenge is the laser piping itself. There are currently no good optical fibers that can handle sufficient optical power and provide long life and reliability. Typically these fibers utilize fluoride or chalcogenide glasses, which are brittle and subject to aging. Another approach is hollow waveguides; however, these are susceptible to vibration and flexure.

An alternate approach to laser piping might be to use a free space coupled link. In this approach mirrors are used with the beam transported in hollow conduit. Even flexible links can be made using rod lenses in a similar fashion to endoscopes. This approach may prove feasible over a limited path length and in installations where there is a well defined path from the laser to the pointing system. However, for most installations the free space link would have to curve around the skin of the aircraft envelope or around internal aircraft components. A free space link will not perform well over such a winding path. The free space link will be distorted by aircraft vibrations and maintenance will be difficult. When a countermeasure system needs maintenance, the basic approach is to identify the broken LRU, replace it and continue the mission. The LRUs are made readily accessible to the aircraft ground crew for quick replacement. If a free space coupled link needs repair, alignment would have to be performed on the aircraft. This means the aircraft would not be free to fly its mission until the link is aligned and fixed. Thus the free space optical link is not a practical solution.

The final approach is mounting the laser source in or on the pointing subsystem. The primary advantage of this approach is no laser piping is required. This approach significantly reduces the risks involved in maintaining the alignment of the laser to the pointing system. The disadvantage of this approach is one laser is required for each pointing system. For most installations this approach also places constraints on the laser size since the laser must be attached directly to or in the pointing system. Since the pointing system must be attached to the aircraft skin there are overall constraints on how far into the aircraft skin it can be mounted and how much weight the supporting aircraft structure can hold. Any new laser upgrades would have to meet these constraints. In the last few years solid state lasers have progressed significantly in the mid IR. In fact there are now multiband, air cooled mid-IR lasers that provide significant jamming energy in a small laser package[5]. Based upon the improvements in laser technology and the limitations in laser piping technology the most practical approach at this time is directly coupling the laser to the pointing subsystem.

Table 8. Comparison of Beam Delivery and Source Packaging Approaches

DESIGN PERFORMANCE CONSIDERATION	 Fiber or Waveguide Coupled	 Free Space Link Coupled	 Direct Coupled
Source Mounting	Not Constrained	Not Constrained	Must be on or near gimbals
Source Packaging	More Flexible	More Flexible	Size and weight constraints
Source Upgradeability	Poor	Medium	Medium
Beam Losses	Med	Low	Low
Beam Distortions	Med	High	Low
MTBF	Med	Low	High
Life Cycle Cost	Med	High	Low
Spectral Bandwidth	High	High	High
Weight	Low	High	None - no intermediate coupling structure
Installation Difficulty	Med	High - requires rigid structure	Low
Risk	High - immature technology	High - very difficult installation, vibration sensitive	Low - reliable coupling method
Initial Cost	Med - only one laser, some installation labor	High - installation and alignment labor intensive	Med - requires one laser per head

[5] Northrop Grumman has demonstrated Band IV lasers in 1996 - a small air cooled, military qualified assembly.

6. Conclusions

In this paper we have presented some of the design tradeoffs that must be considered when designing a DIRCM system. The tradeoffs show that the design process must be iterative since many of the DIRCM subsystems effect the performance requirements of other subsystems. The design tradeoffs also demonstrate the impacts of the high performance probability requirements for each subsystem. Based upon this process several recommendations are made for the design of a DIRCM system including using a high accuracy, good resolution MWS, a 256x256 cryo cooled detector array for missile tracking, a 3 (or 4) DOF pointing system, and coupling the laser source directly to the pointing subsystem. Based upon this hardware configuration, a DIRCM system can be designed to meet the high aircraft survivability requirements.